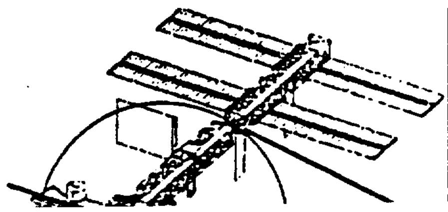
NASA-CR-195717

Space Station Freedom —WP3
Attached Payload Accommodations Equipment User Handbook

7N-18-CR
2374
85P

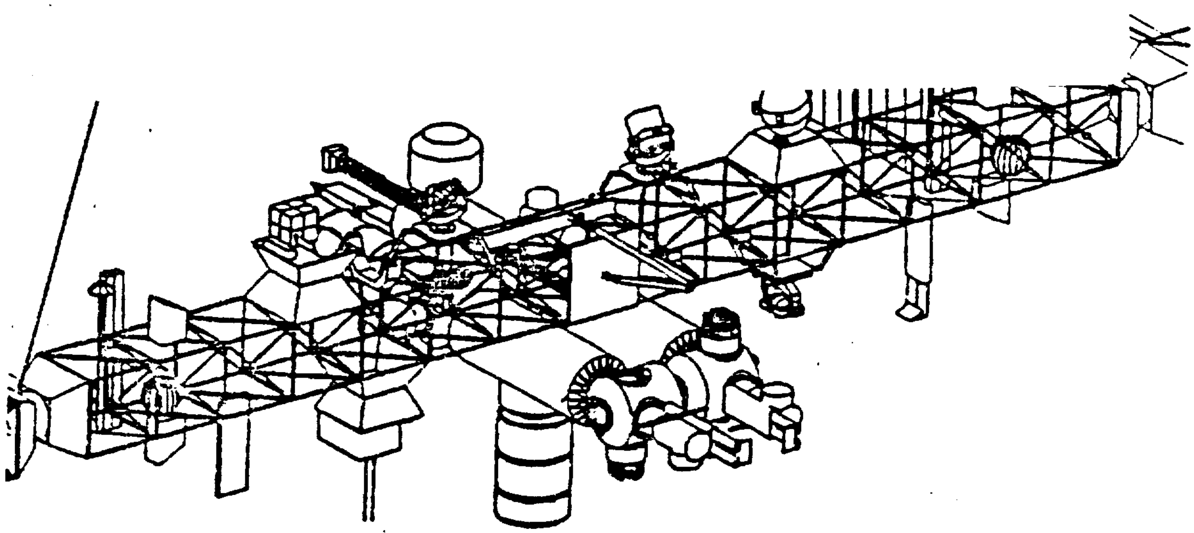


(NASA-CR-195717) SPACE STATION FREEDOM: WP3 ATTACHED PAYLOAD ACCOMMODATIONS EQUIPMENT USER HANDBOOK (GE) 85 p

N94-71741

Unclas

Z9/18 0002374



DR - UID02, March 1989 - Rev. A
Prepared by
GE Astro-Space Division
Valley Forge, PA
Under Contract NAS5-32000
to Goddard Space Flight Center

Table of Contents

	SECTION TITLE	Page
1.0	INTRODUCTION	1
1.1	Space Station Freedom System Overview	1
1.2	Space Station Freedom Program Organization	3
1.3	Attached Payload Accommodations Equipment (APAE)	4
1.3.1	General Description	4
1.3.2	Subsystems Description	6
2.0	SHUTTLE AND SPACE STATION FREEDOM ACCOMMODATIONS AND CONSTRAINTS	
2.1	National Space Transportation System (NSTS)/Orbiter Payload Accommodations	7
2.2	Space Station Freedom Manned Base Accommodations	7
2.2.1	Overview/Background	7
2.2.2	Elements	8
2.2.2.1	Central Truss	8
2.2.2.2	U.S. Laboratory Module	8
2.2.2.3	Resource Nodes	8
2.2.2.4	Logistics Carrier	9
2.2.2.5	Mobile Servicing Center (MSC)	9
2.2.2.6	Flight Telerobotic Servicer	10
2.2.2.7	Attached Payload Accommodations Equipment	10
2.2.3	Distributed Systems	11
2.2.3.1	Electrical Power System (EPS)	11
2.2.3.2	Thermal Control System (TCS)	11
2.2.3.3	SSFMB Information Systems (SSIS)	11
2.2.3.3.1	Data Management System (DMS)	12
2.2.3.3.2	Communications and Tracking	12
2.2.3.4	Guidance, Navigation and Control (GN&C) System	13
2.2.3.5	Extravehicular Activity System	13
2.2.4	Environments	14
2.2.4.1	MSFC/J70 Model of the Neutral Atmosphere	14
2.2.4.2	Penetrating Charged Particles	14
2.2.4.3	Ground Support Equipment (GSE) Design Requirements	14
2.2.5	Coordinate Systems	14
2.2.5.1	Body Coordinate System	14
2.2.5.2	Inertial Coordinate System	14
2.2.5.3	SSFMB and Earth Dynamics	18

Table of Contents

SECTION	TITLE	Page
3.0	APAE DETAILED DESCRIPTIONS	
3.1	APAE Descriptive Overview	19
3.2	APAE Configurations	19
3.3	Payload Attachment (PAS) System and Resources at Each Attachment Site	20
3.3.1	Station Interface Adapter (SIA)	21
3.3.2	Payload Interface Adapter (PIA)	23
3.3.3	System Support Modules (SSMs)	23
3.3.4	Deck Carrier	24
3.3.5	Multiple Payload Adapter (MPA)	24
3.3.6	Grapple Fixture	24
3.3.7	Contamination Monitoring System (CMS)	234
3.4	Payload Pointing System (PPS)	26
3.5	Attitude Determination System (ADS)	27
4.0	PAYLOAD INTERFACES AND ACCOMMODATIONS	
4.1	Structural/Mechanical	28
4.1.1	Self Supported Payloads	28
4.1.2	Payloads Supported on a Deck Carrier	28
4.1.3	Multiplexed Payloads	28
4.1.4	Thermal Control	28
4.1.5	Articulated Payloads	29
4.1.6	Payloads Requiring Attitude Knowledge	29
4.1.7	Deployable Payloads	29
4.2	Data Management System (DMS)	30
4.2.1	Subsystem Description	30
4.2.2	Subsystem Standard Interfaces	31
4.3	Electrical Power System (EPS)	31
4.4	Thermal Control System (TCS)	32
4.5	Robotics	33

Table of Contents

	SECTION TITLE	Page
5.0	GROUND OPERATIONS	
5.1	Overview	34
5.2	User Site Operations	35
5.3	Goddard Spaceflight Center (GSFC) Payload Integration Centers	36
5.4	Launch Site Operations	36
5.4.1	Launch Site Receiving and Inspection (R&I) Operations	37
5.4.2	Launch Element On-line Processing Operations	38
5.4.3	NSTS Testing	38
5.4.3.1	NSTS Safety	38
5.4.3.2	Launch Vehicle Integrated Operations	38
5.5	Post-Mission/Landing Site Operations	39
6.0	PAYLOAD OPERATIONS	
6.1	Overview	40
6.2	Payload Operations Integration Center to SSFMB	40
6.3	Onboard Payload Operational Services	41
6.3.1	Onboard Resource Services	41
6.3.2	Onboard Payload Management Services	42
6.4	On-orbit Ground Services	42
6.5	Command and Control Support	43
6.6	Payload Servicing	43
6.7	User Logistics	43
6.7.1	General	43
6.7.2	User Payload Logistics	43

Table of Contents

SECTION	TITLE	Page
6.8	Training	44
6.8.1	General	44
6.8.1.1	General Training Operations Concept	44
6.8.1.1.1	Familiarization and Basic Knowledge Levels	44
6.8.1.1.2	Proficiency Levels	44
6.8.1.2	WP3 Training Plan	44
6.8.1.3	Certification	44
6.8.2	Crew Payload Training	45
6.8.3	User Ground Support Team Training	45
APPENDIX A:	REFERENCE DOCUMENTS	A-1
APPENDIX B:	NSTS/PAYLOAD ACCOMMODATIONS	B-1
B.1	Standard Payload Accommodations	B-1
B.1.1	Physical Accommodations	B-1
B.1.2	Envelope Available to Payload	B-5
B.1.3	Cargo Bay Liner and Shrouds	B-5
B.1.4	Weight and Center of Gravity	B-5
B.1.5	Avionics Accommodations	B-10
B.1.5.1	General	B-10
B.1.5.2	Electrical Power	B-10
B.1.6	Thermal Accommodations	B-12
B.1.7	GSE Umbilical	B-14
B.2	Small Payload Accommodations	B-14
B.2.1	Physical Accommodations	B-14
B.2.2	Electrical Power	B-15
B.2.3	Thermal Accommodations	B-15
B.3	Remote Manipulator System (RMS)	B-15
B.4	Optional Services and Accommodations	B-15
B.4.1	Auxiliary DC Power	B-17
B.4.2	AC Power	B-17
B.4.3	Standard Umbilical Retraction and Retention System	B-17
B.5	Induced Environments	B-18
B.5.1	Vibration Caused by Noise	B-18
B.5.2	Payload Limit Load Factors	B-18
B.5.3	Pressure and Venting	B-18
B.5.4	Contamination Control	B-20
APPENDIX C:	WORST CASE PAYLOAD ENVIRONMENTS (TBR)	C-1
APPENDIX D:	DEFINITIONS	D-1
APPENDIX E:	ACRONYM LIST	E-1

Table of Contents

LIST OF FIGURES AND TABLES

		Page
Figure 1-1a.	Baseline Configuration	2
Figure 1-1b.	Baseline Configuration - top view	2
Figure 1-1c.	Baseline Configuration - forward view	2
Figure 1-2.	Orbits for Space Station Freedom and Platform	3
Figure 1-3.	Space Station Freedom Program organizational Relationships	5
Figure 1-4.	GSFC WP3 Organization	5
Figure 1-5.	Typical attached payload accommodations	6
Figure 2-1.	Pressurized Module configuration	9
Figure 2-2.	Mobile Servicing Center	10
Figure 2-3.	Space Station Freedom Body Coordinate System	15
Figure 2-4.	Space Station Freedom Orbit-Earth relative motion	16
Figure 2-5.	Yearly Earth-Sun orientation	17
Figure 3-1.	APAE Typical Configurations	19
Figure 3-2.	Payload mechanical attachment interfaces	22
Figure 3-3.	Large self-supported payload	23
Figure 3-4.	User-supplied pallet mounted payload	23
Figure 3-5.	Deck Carrier Assembly	25
Figure 3-6.	Multiple payload/Deck Carrier configuration	25
Figure 3-7.	Single payload/Deck Carrier configuration	25
Figure 3-8.	Single payload/Deck Carrier configuration (assembled view)	25
Figure 3-9.	Payload and Payload Pointing System (PPS)	27
Figure 3-10.	APAE/PPS functional block diagram	27
Figure 3-11.	APAE/ADS functional block diagram	27
Figure 4-1.	Location of utility ports for attached payloads	29
Figure 4-2.	APAE/DMS functional block diagram	30
Figure 4-3.	APAE/EPS functional block diagram	31
Figure 4-4.	APAE/ATCS functional block diagram	32
Figure 5-1.	Typical payload integration schedule	34
Figure 5-2.	Typical payload/APAE integration hardware exchanges	35
Figure 5-3.	Typical flow of integration activities at a PI Center	37
Figure 5-4.	Typical flow for R&I activities	37
Figure 5-5.	Typical flow for on-line testing activities	38
Figure 5-6.	Typical flow for launch vehicle integrated operations	38

LIST OF FIGURES AND TABLES

		Page
Figure B-1.	Principal Orbiter interfaces with payloads	B-2
Figure B-2.	Attach fittings for Payloads	B-3
Figure B-3.	Three- and five-point Loads support	B-4
Figure B-4.	Orbiter coordinate system and cargo bay envelope	B-6
Figure B-5a.	View of payload looking aft	B-7
Figure B-5b.	Payload coordinates showing relationship to each Orbiter axis	B-7
Figure B-6a.	Center-of-gravity limits for cargo along the Orbiter Z-axis	B-8
Figure B-6b.	Payload center-of-gravity limits along the Orbiter X-axis	B-9
Figure B-6c.	Allowable center-of-gravity envelope along the Orbiter X-axis	B-9
Figure B-7.	Standard interface panel configuration	B-11
Figure B-8.	Cargo bay thermal environment during the phases of a typical flight	B-13
Figure B-9.	Manipulator arm assembly location on the Orbiter	B-16
Figure B-10.	Load factors for component mountings	B-18
Table 3-1.	Space Station Freedom Manned Base Resources Available to Attached Payloads via APAE	21
Table 3-2.	Attached Payload Pointing Capabilities	26
Table B-1.	Ground purge capability	B-13

UID02 Space Station WP3 APAE User Handbook

Table of Contents

TBD/TBR List

Paragraph Reference		Page
TBDs		
1.2	Prime Contractor for FTS	4
2.2.2.2	Details of Crew Support Station	8
2.2.2.4	Length of Pressurized Logistics Carrier	9
2.2.3.1	Loads for SS provided power converters	11
3.4	Jitter capability for attached payload pointing	26
3.4	Stability capability for attached payload pointing	26
5.4.3.1	Document # for Space Station Freedom/NSTS Safety Requirements	38
6.1	Relationships among POIC, DOC, ROC. SSCC, etc.	40
6.3.1	On-line mass storage capacity	41
6.7.2	Support for payloads during ascent/descent in NSTS	43
6.7.2	Capabilities for ELV payload logistics	43
Appendix B		
B.4.2	Volt-amps available to payload during ascent	B-16
TBRs		
2.2.3.3.1	Data Rate Between APA and Lab module (up to 100 Mbps)	12
3.3.1	SIA height above truss & dimensions of mounting plate (5 feet & 13 feet)	21
3.3.4	Number of Multiple Payload Adapters	24
3.4	Maximum payload mass moments of inertia (11,400 kgm^2)	26
3.5	Sensor data for ADS (Sun, Earth)	27
4.1.2	Maximum number of compatible payloads	28
4.1.3	Standard size for a MPA plate (2 places)	28
6.3.1	Daily volume capacity of User data (1 Terabyte)	41
6.3.1	SSFMB data rates of 100 Mbps	41
6.3.1	On-board buffer storage capacity (1 Terabyte)	41
Appendix C		
C	Worst Case Payload Environments	C-1

REVISED UID02 Space Station Freedom WP3 APAE User Handbook

1.0 INTRODUCTION

The NASA Space Station Freedom Program (SSFP) encompasses the design, development, test, evaluation, verification, launch, assembly, operation and utilization of a set of spacecraft based in Earth orbit and their supporting ground facilities. The Space Station Freedom set of spacecraft will be designed and built by the U.S. Government and its International Partners, the European Space Agency (ESA), Canada and Japan. The set of spacecraft includes: a Space Station Freedom manned base (SSFMB) to which scientific, technological and commercial payloads will be secured either external or internal to the manned pressurized module; one (or more) unmanned Polar Orbiting Platforms (POPs); possible co-orbiting platforms (COPs); and possible manned and unmanned sortie vehicles. The SSFP provides the means for enabling a permanent human presence in space, as well as a variety of scientific, technological and commercial activities.

The purposes of this document are to:

- Supply information for Users of the Space Station Freedom to aid in proposing and designing payloads that will be attached to the SSFMB central truss
- Provide background information regarding operations on the Space Station Freedom.

Attached payloads are Space Station Freedom Payloads that operate external to the the pressurized modules of the SSFMB. Resources such as power, heat rejection, structural support, orientation, command and control, and data handling are provided to attached payloads via hardware and software identified as Attached Payload Accommodation Equipment (APAE). APAE physically supports and transfers required resources to a diverse group of attached payloads. Provisions are made for transportation to orbit, installation and check out on the SSFMB, normal operations, servicing, repair, removal and return to the Earth.

The data contained herein should not be considered as final. Space Station Freedom design is in the development process, and significant changes are possible. Updates of this document will be provided as warranted by design developments.

1.1 Space Station Freedom System Overview

The Space Station Freedom includes a permanently manned research facility in low-Earth orbit, unmanned Polar Platforms, and an associated ground-based infrastructure. The Baseline SSFMB, (**Figures 1-1 a, b & c**), features a 508 foot (155 meters) transverse truss with four centrally located pressurized modules providing habitation and research laboratory space. Located at each end of the truss are photovoltaic arrays which will be shared by the SSFMB and all User payloads. Provisions are made to attach payloads along the central portion of the transverse truss. Power, heat rejection, structural support, orientation, command and control, and data handling are provided to the attached payloads at utility ports located on the central truss assembly.

The four pressurized modules include laboratory and habitation facilities. Linking the pressurized modules are resource nodes, passageways outfitted with racks providing extra space for equipment. The modules accommodate a maximum of eight crewmembers.

The Baseline SSFP provides four utility ports at which, at least, two sets of Attached Payload Accommodation Equipment (APAE) and payloads can be attached. APAE provides the standard interface between the SSFMB and the User payload and/or payload support structure.

Figure 1-2 is an illustration of the orbits of the SSFMB and polar platforms. Free flying platforms, launched into polar orbit, will enable views of every point on Earth. The baseline SSFP configuration includes the SSFMB and the unmanned polar orbiting platform.

The SSFMB is designed to operate at a 28.5° inclination from 150 nmi (276 km) to 270 nmi (500 km) with a nominal operating altitude between 220 and 250 nmi. Pressurized and unpressurized logistics carriers provide supplies and equipment. Limited provisions for payload servicing are available. A Mobile Servicing

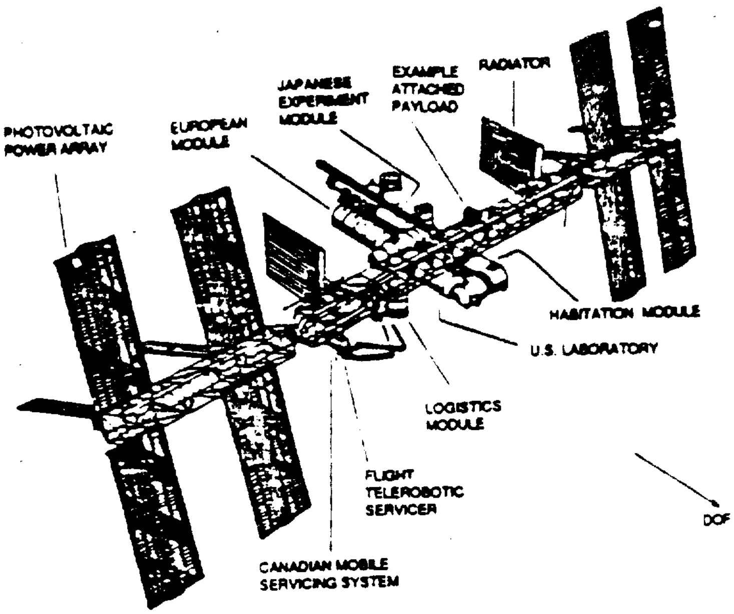


Figure 1-1a. Baseline configuration.

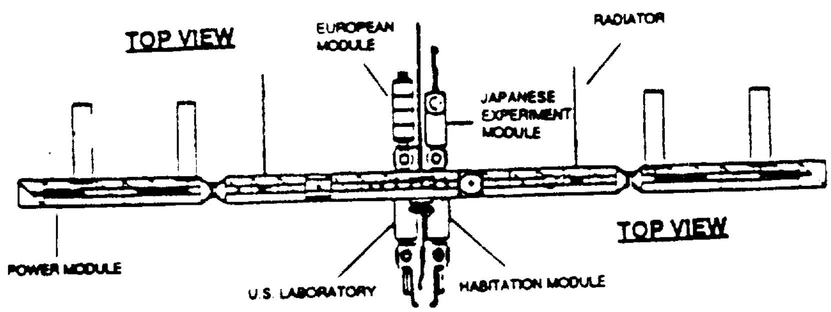


Figure 1-1b. Baseline configuration - top view.

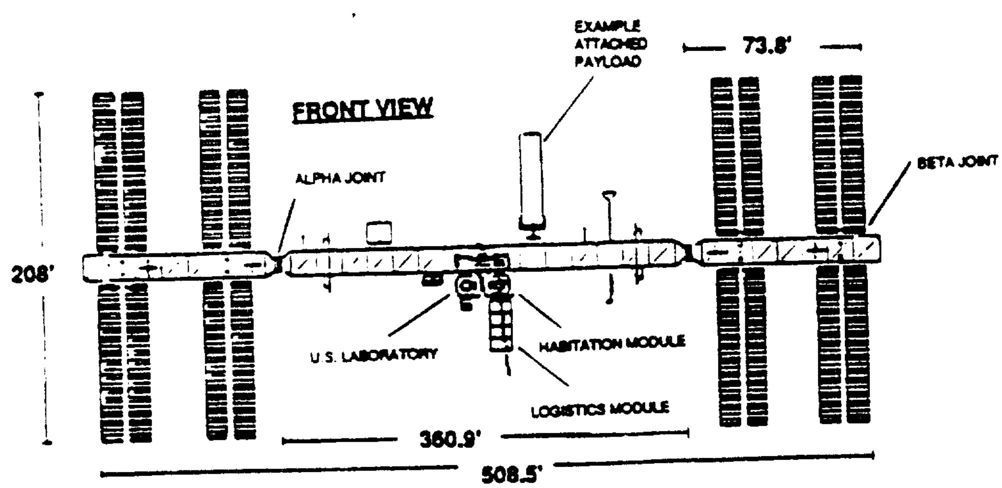


Figure 1-1c. Baseline configuration - forward view.

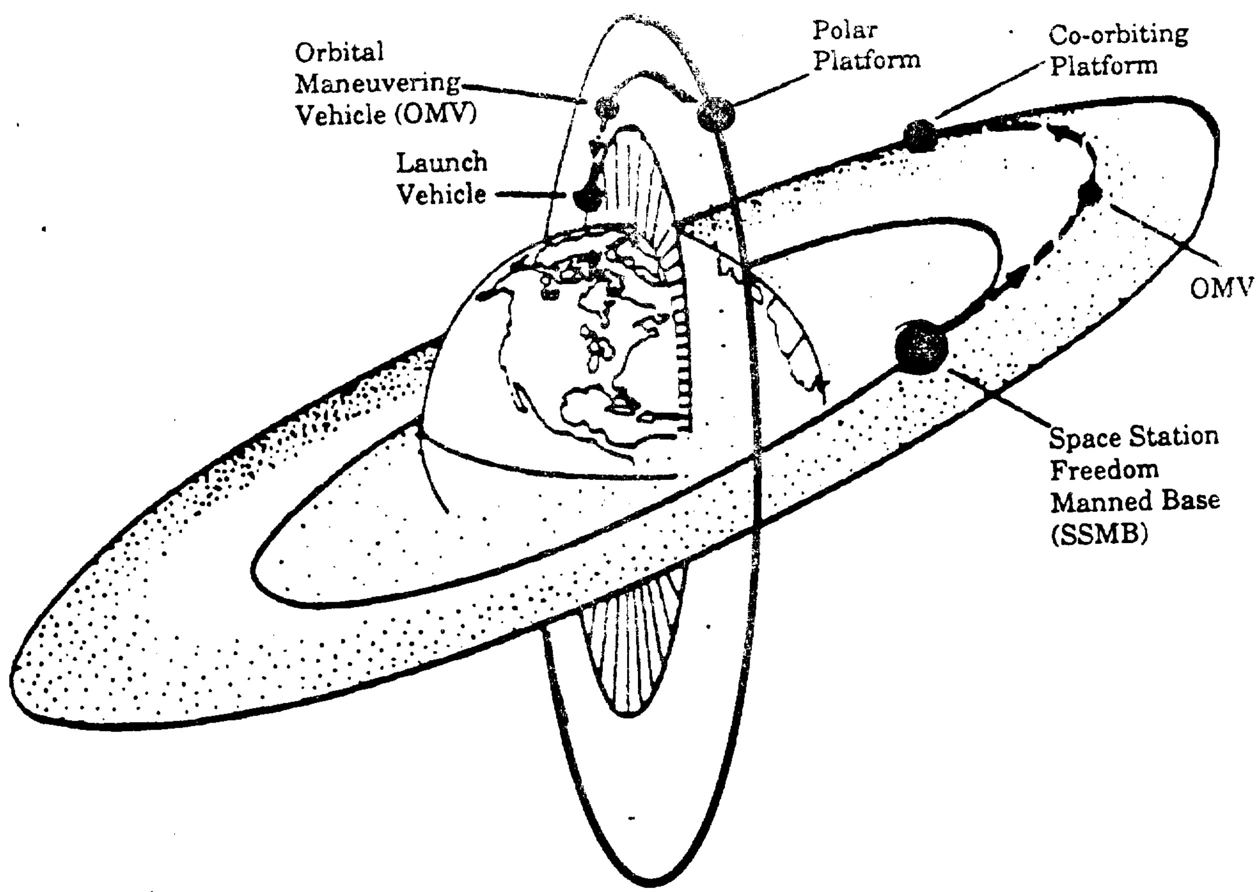


Figure 1-2. Orbits (not to scale) for Space Station Freedom and platforms.

Centre (MSC) and a Flight Telerobotic Servicer (FTS) will be used to assist in the remote assembly of payloads and payload equipment and for a number of servicing tasks.

The SSFMB will provide payload support subsystems including data management, power, thermal control, communications and tracking, guidance, navigation and control, environmental control, human life support and fluid management.

1.2 Space Station Freedom Program Organization

The SSFP is organized into three levels:

- Level I is the Office of Space Station Freedom that administers the overall program through the formulation of policy, external interfaces and agreements, budgets, and evolution/advanced development.
- Level II is the Space Station Freedom Program Office which manages and integrates the development of the overall system and its operational capability through systems engineering, analyses, Space Station Freedom elements integration, program requirements definition and assessment, and budget execution/control.
- Level III consists of individual Work Packages where the development of the various Space Station Freedom Elements are managed and executed. In addition to the design, development, test and engineering (DDT&E) efforts, Level III is responsible for system element integration, validation, and operation.

The four Work Packages (WP) of Level III and their basic contents are:

- WP1 is the responsibility of the Marshall Space Flight Center (MSFC), with Boeing as the prime contractor. This work package includes the U.S. (pressurized) modules (habitation and laboratory), propulsion system, and US logistics modules. MSFC also has the responsibility for adapting the Orbital Maneuvering Vehicle (OMV) for Space Station Freedom applications
- WP2 is under the Johnson Space Center (JSC), with McDonnell Douglas as the prime contractor. This work package includes the structure, Shuttle interfaces, control and communications, data system, thermal control, distribution of resources, crew quarters and the extravehicular activity (EVA) planning.
- WP3 is managed by the Goddard Space Flight Center (GSFC), with the GE Astro-Space Division as the prime contractor. This work package includes the Space Station Freedom Platforms, Customer Servicing Facilities (CSF) and the APAE. GSFC is also responsible for the FTS with TBD as the prime contractor.
- WP4 is the responsibility of the Lewis Research Center (LeRC), with the Rockwell Rocketdyne Division as the prime contractor. This work package includes power generation, conditioning, and storage.

In addition to the four WPs, launch support is provided by the Kennedy Space Center (KSC). ESA will contribute a COP and a Columbus pressurized module. Japan will contribute a pressurized Japanese Experiment Module (JEM). Canada will provide the MSC.

Each Space Station Freedom User interfaces with the SSFP via a single point-of-contact through which there is coordination with each of the three levels. Initially, a User is introduced into the Program through Level I. The allocation of a Users mission to a particular Work Package system element and schedule is performed by Level II. The analytical and physical integration of the User's mission with the SSFMB is performed through the appropriate Level III work package. For attached payloads this is WP3.

Figure 1-3 depicts the relationships of the SSFP organizations, including the interfaces of each level with other government entities and industrial contractors. For instance, the integration effort at Level I is supported by Grumman (Program Support Contractor), Lockheed (Software Support Contractor) and Boeing (Technical and Management Information System). The figure shows WP1 through WP4 plus Launch Support.

Figure 1-4 shows the WP3 NASA Organization at the GSFC. Supporting the SSFP Director and the Associate Director are: the Associate Director of Space and Earth Science for Space Station Freedom; the Chief Engineer; the program management offices; the Systems Engineering and Integration Office; and the Ground Systems Operations/Information/Utilization organization. The latter includes the Utilization Office that represents the User's interests in the WP3 organization.

1.3 Attached Payload Accommodations Equipment (APAE)

1.3.1 General Description

The central truss on the SSFMB has provisions for the attachment of payloads along its length on the top (zenith), bottom (nadir), and back (anti-velocity) faces between the two alpha rotation joints (See Figure 1-1). Utilities provided include power, thermal control, structural support, pointing, command and control, video, and data handling. As an option, APAE can also provide pointing to compensate for SSFMB motion or to seek specific targets and attitude determination for payloads that require knowledge to an accuracy better than that provided by the SSFMB.

The APAE provides the accommodations for external User payloads attached to the central truss of the SSFMB. The APAE provides all hardware and software interfaces required for the installation, checkout, operation, maintenance, repair and removal of payloads attached to the central truss.

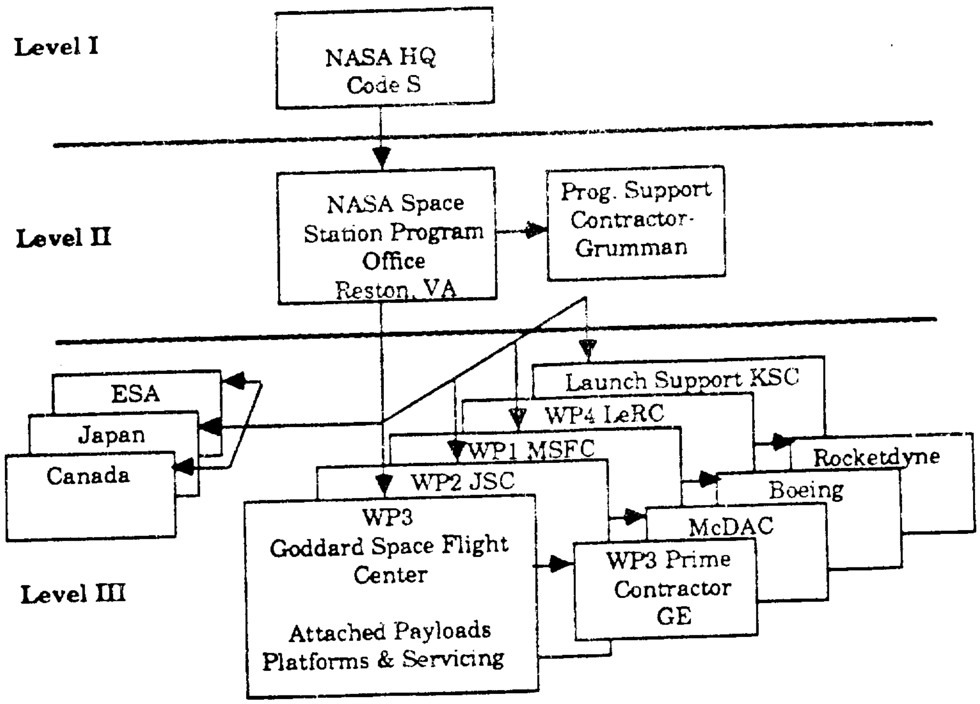


Figure 1-3. Space Station Program Organizational Relationships

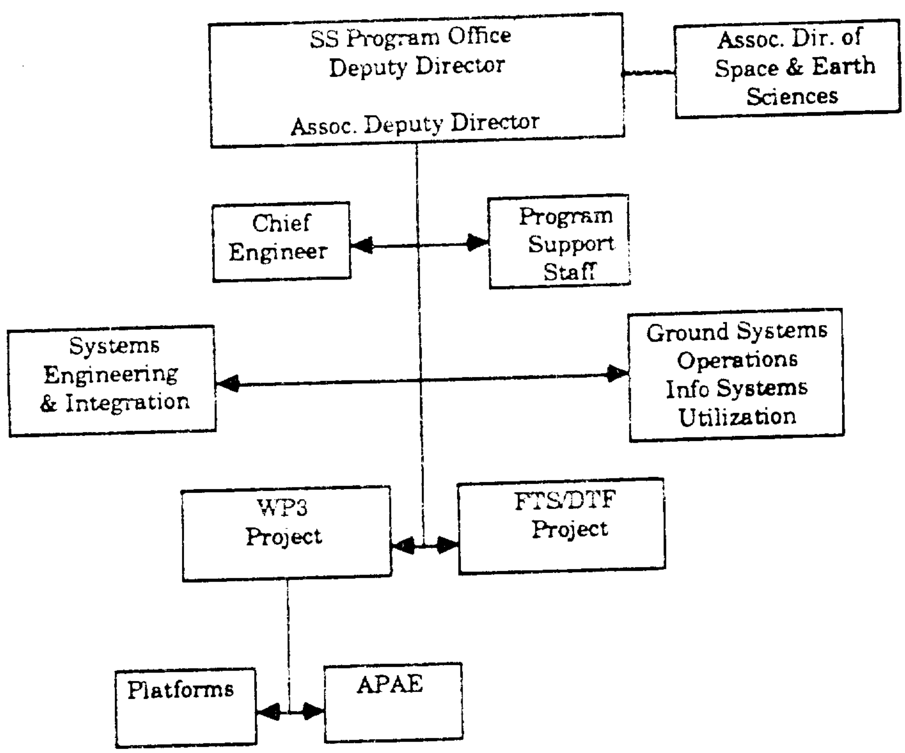


Figure 1-4. GSFC WP3 Organization

The APAE is capable of accommodating large and moderately sized single payloads and groups of small payloads. Space Station Freedom services to be provided to the payloads include:

- Launch to orbit and return to ground
- Transport, installation and removal on SSFMB of attached payloads
- Power, thermal, data, command, and video resources
- Normal payload operations, in some cases servicing and repair
- Maintenance and repair.

1.3.2 Subsystems General Description

All interfaces between an attached payload and the SSFMB will be through SSFP provided APAE. The main mechanical (structural) interface components of the APAE are the Station Interface Adapter (SIA), the Payload Pointing System (PPS), Payload Interface Adapter (PIA), the Deck Carrier and, if required, the Payload Pointing System (PPS). Typical implementations of payload attachments are shown in **Figure 1-5**. The SIA provides standard mounting and resource interfaces to the SSFMB central truss, while the PIA extends the resource interfaces to the payload. The Deck Carrier is capable of providing structural support for a payload that must be accommodated within the cargo bay of the Space Shuttle, but does not span the Shuttle attach points. The PPS is a three axis gimbal to which a payload can be mounted.

Other items include System Support Modules (SSM), Multiple Payload Adapter (MPA) the Attitude Determination System (ADS), and Grapple Fixtures. The SSM provides control and distribution of the SSFMB resources, including data handling, to the payload. MPAs provide the capability to attach up to four payloads to the deck carrier.The function of the ADS is to measure the orientation of the payload attached to the SSFMB and is primarily used in conjunction with the PPS. Grapple fixtures provide mechanical and electrical interfaces to the APAE and/or payload during handling operations.

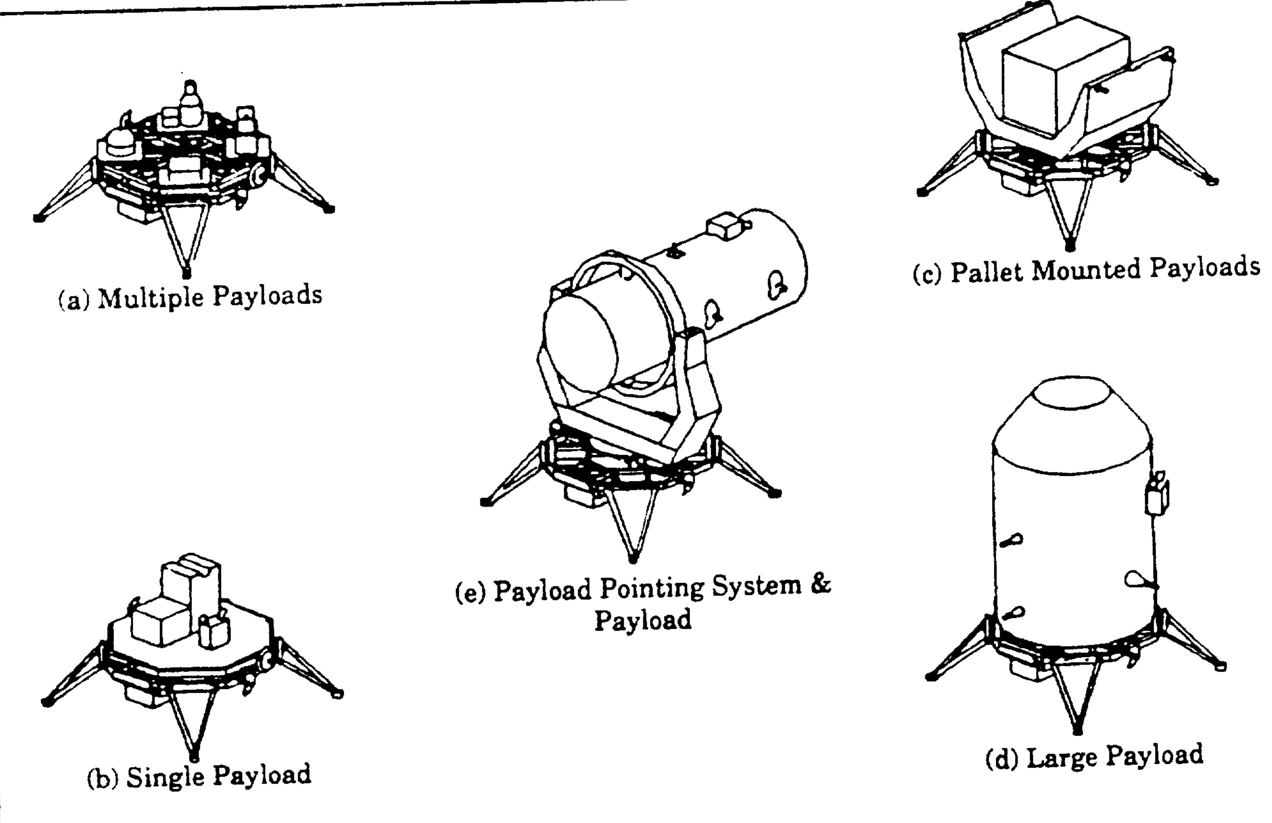


Figure 1-5. Typical attached payload accommodations

2.0 SHUTTLE AND SPACE STATION FREEDOM ACCOMMODATIONS AND CONSTRAINTS

2.1 National Space Transportation System (NSTS)/Orbiter Payload Accommodations

While transport to the SSFMB by means of an expendable launch vehicle (ELV) is a possibility, transportation will normally be provided by the NSTS, a/k/a the Space Shuttle. The majority of attached payload Users will interface to the Shuttle through a Space Station Freedom Program supplied Deck Carrier or User supplied Payload Support Structure. Some instruments may be of a size such that direct interface with the Shuttle is required. All instruments and support equipment will be required to withstand the Shuttle induced environment and meet Shuttle safety requirements.

Attached payloads developers, designers and APAE Users will receive support from the WP3 contractor for requirements understanding, development and integration regarding Shuttle accommodations and constraints.

The NSTS will provide transportation to and from the SSFMB. Specific interfaces with the NSTS for attached payloads will be provided by a Payloads Accommodations Manager. (See Section 5.1.) Appendix B provides background data on the NSTS with emphasis on its use as a cargo transporter. Appendix B also summarizes the accommodations, major design and environmental factors that need to be considered by the payload designer when utilizing the Shuttle to transport the payload to the SSFMB. The information in Appendix B was, in general, extracted from the Space Transportation System Users Handbook, JSC-07700 Volume XIV. For additional details the User is referred to this document.

2.2 Space Station Freedom Manned Base Accommodations

2.2.1 Overview/Background

The SSFMB Baseline configuration evolved from an extensive analysis of scientific and commercial User requirements, as well as transportation, engineering and technology factors. The Phase B preliminary design firmly established an architectural concept for the SSFMB configuration which was subsequently scaled down to the present Baseline Configuration. Options concerning the assembly process, safety, transportation capability, operations and early productivity were also developed. An Operations Task Force established operational concepts to be used in Space Station Freedom design.

An assembly sequence has been developed to serve as a starting reference upon which the detailed design and development of the Space Station Freedom Program Elements (SSPEs) will be based. This sequence will assure that the SSFMB resources will be adequate to support the operations of payloads when they are delivered to orbit. This sequence places priority on early utilization prior to permanent habitation (For additional information see "Space Station Freedom Assembly Sequence Trial Payload Manifest", Release 1.0, December 9, 1988.)

This revised architectural configuration will be used as a baseline for program design and development during Phase C/D. The design will mature as the Preliminary Design Review (PDR) and the Critical Design Review (CDR) phases are completed. The details provided in this report are subject to change as Phase C/D proceeds.

The SSFMB will be powered by two power modules, each composed of two pairs of photovoltaic arrays. T-shaped 73.8 foot (22.5 meters) long power modules will be attached to each end of the central truss with two rotating alpha joints. The solar arrays are attached to the power modules through two rotating beta joints (See **Figure 1-1**). Rotation of these two sets of joints will be used to keep the solar arrays perpendicular to the sun. The power modules will supply an average total of 75 kilowatts (kW) of electrical power.

The SSFMB will include a MSC provided by Canada. This system will be used in the assembly of the SSFMB and for a number of servicing tasks. There will also be a Flight Telerobotic Servicer. The FTS will be used during the assembly of the SSFMB and to service payloads.

Other elements will be provided by the SSFMB International Partners. These are the Columbus pressurized module provided by the European Space Agency (ESA) and the pressurized Japanese Experiment Module (JEM).

The SSPEs are assembled to make up the SSFMB. Program elements comprise the hardware that is not involved with distributing a utility or service. Distributed systems provide those functions where end-to-end performance is located in two or more elements. The SSFMB will have a number of distributed systems to provide data management, thermal control, communications and tracking, guidance, navigation and control, environmental control, human life support and fluid management.

2.2.2 Elements[1]

2.2.2.1 Central Truss

The central truss (**See Figure 1-1**) will be a 360 foot (110 meter) long assembly providing structural stiffness and dimensional stability to the entire SSFMB. The truss will also provide the structure for integration and installation of all the elements and systems, including the modules, that make up the SSFMB.

The central truss will be a frame-like structure made up of longerons, battens, and diagonal struts designed to be assembled in space. Made of composite materials, these members will be attached to corner fittings forming a beam truss of sequential cubic bays measuring 16.4 feet (5 meters) wide from strut center line to strut center line.

The overall truss assembly will include the central truss structure, extravehicular activity (EVA) truss equipment to facilitate crew movement about the SSFMB, an external lighting system, utility distribution trays, resource pallets, and an alpha joint and drive mechanism to turn the photovoltaic power modules. Utility distribution trays will house the subsystem distribution lines — thermal, power, fluid and data management — for the SSFMB. Utility ports, equipped with common interfacing hardware, provide for external attached payloads via the associated APAE.

2.2.2.2 U.S. Laboratory Module

The U.S. laboratory module (**Figure 2-1**) will be located below the lower face of the central truss. The laboratory will be a pressurized cylinder, 14 feet (4.3 meters) in diameter and approximately 44 feet (13.4 meters) in length. The ports at either end of the module will be 7 feet (2.1 meters) in diameter. The lab module may house a Crew Support Station (CSS) which can be configured for control of attached payloads. The module also contains a viewing port for visual observation of the external payloads. Details of the CSS are TBD.

2.2.2.3 Resource Nodes

The SSFMB will have four resource nodes, located at each end of the habitation and U.S. laboratory modules. (See **Figure 2-1**). The nodes will be small pressurized cylinders that will generally serve as: command and control centers; pressurized passageways to and from the various modules; and possible accommodation for some experiment racks. The nodes will be pressurized cylinders approximately 14 feet (4.3 meters) in diameter and 17 feet (5.2 meters) long. One of the resource nodes may house a CSS which can be configured for control of attached payloads. Certain nodes will contain berthing mechanisms for temporary attachment of either the Space Shuttle or the logistics modules. One or more cupolas may be attached to node ports to allow direct viewing of external activities. The nodes will also contain docking equipment and hatches.

1.) The SSFMB Elements discussed herein are limited to those elements of specific relevance to attached payloads and APAE and are not intended to be an overall description of Space Station Freedom or its capabilities.

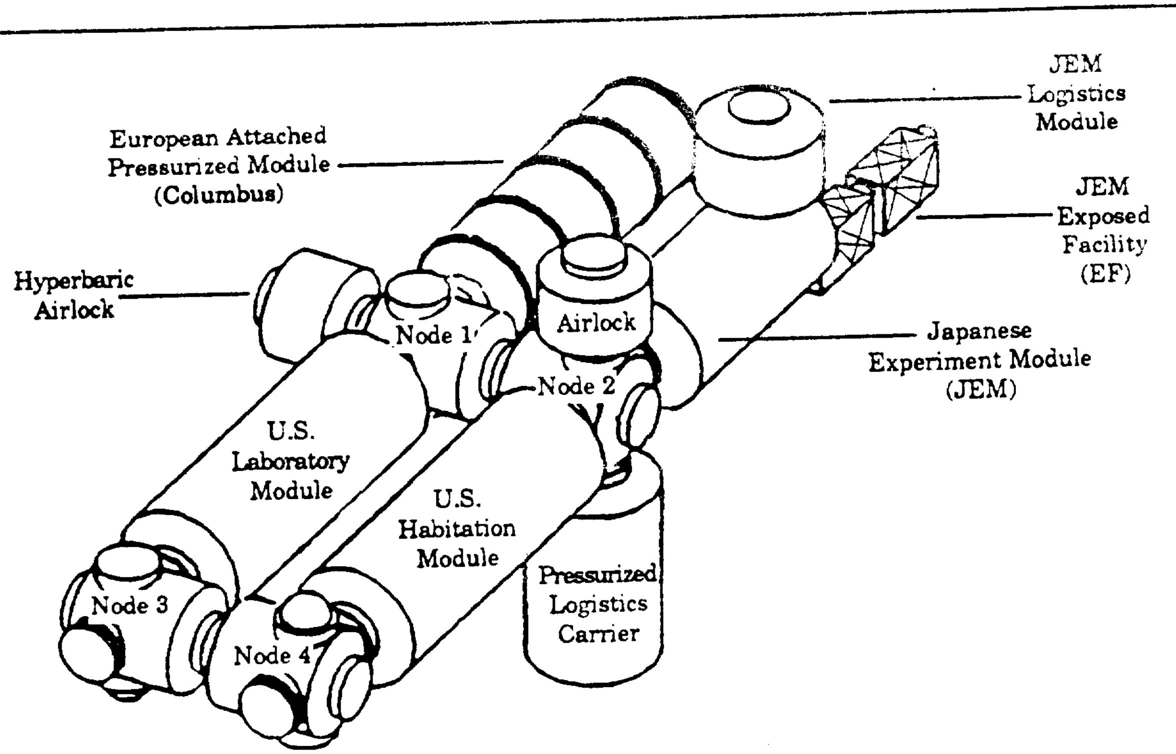


Figure 2-1. Pressurized module configuration.

2.2.2.4 Logistics Carrier

There will be two types of Space Station Freedom logistics carriers: pressurized and unpressurized. Both will be used to transport equipment and fluids to the SSFMB and to return experiment results, equipment, and waste products back to Earth. The pressurized carriers will transport equipment and supplies which require a pressurized, protected environment. Both kinds will be reusable and may be used as carriers for attached payloads.

The pressurized logistics carrier will be located on the bottom of the SSFMB, berthed either at Node 1 or Node 2 (See **Figure** 2-1). The carrier will be approximately 14 feet (4.3 meters) in diameter and **TBD** feet (TBD meters) in length. The carrier will have both Orbiter and SSFMB attachment mechanisms. The internal structure will consist of a rigid surface for the support of distributed subsystems and utilities, secured stowage, and facilities for interchangeable racks that contain spare parts, experiment parts, consumables, and Orbital Replacement Units (ORUs). (ORUs are modular components of the SSFMB that can be removed and replaced on orbit.)

Unpressurized logistics carriers will also berth at SSFMB ports. These carriers will be designed to carry equipment and supplies that do not require a pressurized, protected environment. This could include ORUs for the SSFMB, attached payloads and experiments, and fluids.

2.2.2.5 Mobile Servicing Centre

The MSC shown in **Figure 2-2** is an automated facility used for assembling, routine servicing, and maintaining the SSFMB and attached payloads.

The Mobile Remote Servicer (MRS), provided by Canada, and the U.S. provided mobile transporter (MT) will make up the MSC. The MT will ride along rails mounted on the front face of the central truss, providing mobility for the MSC. The MRS will consist of a base structure mounted to the MT, a Remote Manipulator System (RMS) similar to the one on the Orbiter, an Astronaut Positioning System (APS), and a Special

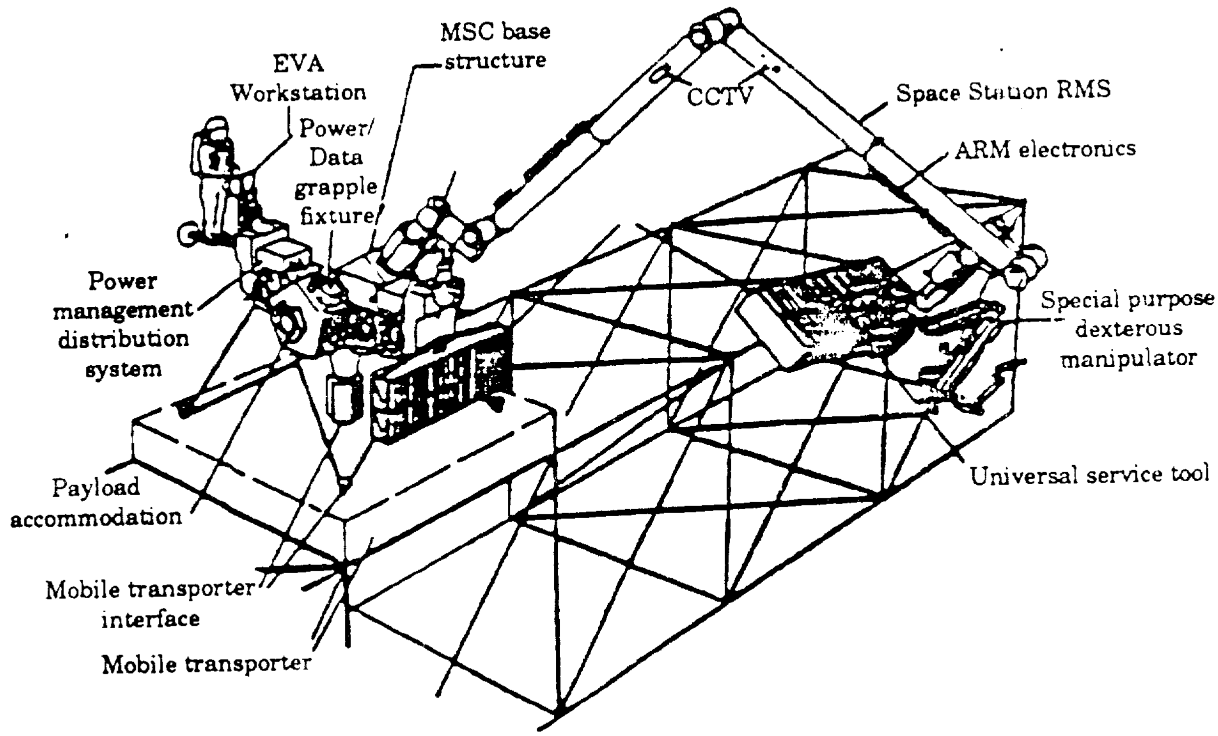


Figure 2-2. Mobile Servicing Centre

Purpose Dexterous Manipulator (SPDM) which acts as the "hands" of the system. The APS will be similar to the RMS, except that it will have additional restraints designed to secure a suited astronaut. The SPDM will be designed to perform change out of ORUs and attached payloads.

The MSC will be able to remove cargo such as attached payloads and APAE from the Shuttle cargo bay, transport that cargo to the point of assembly or storage, support EVA assembly functions with crew positioning devices, and provide post-assembly inspection. The MSC will also transport Space Station Freedom elements and attached payloads to/from locations on the SSFMB as well as provide deployment and retrieval functions.

2.2.2.6 Flight Telerobotic Servicer

The FTS will be a highly automated telerobotic device capable of precise manipulations including routine and hazardous tasks. The FTS will be used to reduce EVA time and risk. Proposed initial functions include: installing truss members; installing fixtures such as the SIA on the central truss; changing out of ORUs; mating the thermal utility connectors; and performing inspection tasks.

Astronauts will operate/monitor the FTS during either direct manipulator control or programmed command sequences. The FTS is designed to be operated from several different workstations as the SSFMB develops. FTS hardware and software are structured in a modular fashion to ensure serviceability. The FTS configuration is flexible to facilitate technological upgrade.

2.2.2.7 Attached Payload Accommodations Equipment

APAE will be the SSFP supplied equipment used to mount and operate external scientific payloads. The APAE will include a structural interface between the SSFMB and the payloads, and distributed systems outlets to supply the payloads with power, thermal control, and command and data links. The APAE will be designed to accommodate a variety of external payloads from pre-integrated instrument pallets, to single instruments requiring gimbaled pointing.

There are four utility ports (also called attach points) located along the central truss. Two sets of APAE will be provided in the Baseline configuration. One of these sets will include a payload pointing system for instruments which must be continuously oriented.

2.2.3 Distributed Systems

2.2.3.1 Electrical Power System (EPS)

The SSFMB EPS provides all User and housekeeping electrical power and all auxiliary power systems required by the SSPEs. Contingency power will be provided to enable the SSFMB to return to normal operation at the end of one orbit without solar input. Power down to minimum safe levels will be utilized to minimize the impact on the EPS.

The EPS will generate and distribute an average of 75 kilowatts (kW) of electrical power to the SSFMB housekeeping functions and Users. The EPS provides 120 Vdc power to the User interface. This standard power will be used by all U.S. and international partner elements of the SSFP including manned base modules, attached payloads, and other equipment. Converters may be available to provide 28 Vdc with (**TBD**) loads and 120/208 Vac, 60 Hz with (**TBD**) loads.

The overall distribution subsystem will be composed of equipment necessary to process, control, and distribute power to other SSFMB subsystems, elements, and attached payloads. The distribution equipment will include cables, load converters, transformers, regulators, switches and other standard electrical equipment.

Grounding will be at a single point. All equipment operating from a common, isolated power source will be commonly bonded such that fault currents will be limited for safety. Redundant equipment power sources will share a common single point ground. All grounding shall conform to SSP 30240, SSFMB Grounding Standard. All wiring will be short circuit protected with replaceable or resettable devices or be current limited.

2.2.3.2 Thermal Control System (TCS)

The TCS will control the temperature and heat distribution throughout the SSFMB, and reject the heat produced by on-board systems. The TCS is composed of a Passive Thermal Control System (PCTS) and an Active Thermal Control System (ATCS). The PTCS utilizes conventional control techniques such as radiators and blankets. The ATCS is a two-phase ammonia system for external portions of the SSFMB. Waste heat acquisition, transport and rejection will be provided for each attached payload to permit thermal control for a wide range of payloads. An integrated thermal utility bus will collect and transport waste heat from the attached payloads to central thermal bus radiators. The baseline ATCS will be capable of rejecting heat from electrical loads of 75 kW, with up to 300 kW as a growth option.

The central bus ATCS consists of four independent loops. There will be primary and redundant loops at 70°F (21°C) and primary and redundant loops at 35°F (2°C). The temperatures of the 70°F (21°C) loops can be adjusted so that they can run at 35°F (2°C), in the event of a malfunction of the lower temperature loops. These four loops will interface with a modularized, erectable central heat pipe radiator system. This radiator assembly, located on the central truss, will include a rotary fluid joint that permits the radiator to be rotated away from the radiant heat of the sun.

For truss attached payloads, thermal acquisition is provided at the payload attachment interface. Separate APAE thermal loops will transport waste heat to the central thermal bus heat exchangers.

2.2.3.3 SSFMB Information Systems (SSIS)

Information processing and communications capabilities will be accomplished with a network of related systems, collectively called the Space Station Freedom Information System (SSIS). Using the on-board Data Management System (DMS) and the Communications and Tracking System (C&T), the SSIS will provide information flow within the SSFMB for housekeeping and User purposes, and to and from Earth.

The SSIS will be transparent to both the Users and operators of the SSFMB. The User on Earth will, in effect, have a direct link to the SSFMB even though his data signals will be switched through a complex network. Standard formats and database managers will permit the User to share operational databases and transport software throughout the SSIS.

2.2.3.3.1 Data Management System

The DMS will be an on-board computer system to provide the hardware and software resources necessary to support the data processing and control needs of Space Station Freedom systems, elements, and payloads. The DMS will also provide a standardized, homogeneous operating environment and human-machine interfaces for both the crew and ground operators.

The DMS provides database access, command and control, data transmission, data processing and handling, and man-machine interfaces for the Users and subsystems and interfaces for international element onboard information systems. Users and subsystems will be able to initiate on-line capabilities such as command generation, data handling, graphics, health monitoring, planning, scheduling and training activities, display of performance and trend data, and monitoring of properly interfaced payloads. The information and data management services provided include: data storage; processing and handling; presentation; and onboard networking services adequate to accommodate most User requirements. The DMS will support all on board subsystems such as electrical power, thermal control, data management, communications, attitude control and orbit altitude maintenance of the SSFMB and platforms. Also provided by the DMS are on-board security and encryption for User's sensitive data.

Access to the services is provided through standard, network interface nodes. Under normal operating conditions, the operating system and network access protocols will provide transparency of the DMS to the User. The User interface to DMS will be through a workstation containing a Multi-purpose Applications Console (MPAC). The MPAC will provide for monitoring, training, testing, Caution and Warning, display and crew operations.

The DMS will support transmission of data with User selectable error performance commensurate with the type of data being transmitted. Users will be able to achieve a Bit Error Rate (BER) of as little as 10^{-8}. The DMS will provide for storage and activation of stored command sequences. Real time command and control can be initiated by the system, ground operators or the crew. The DMS will be able to route 32 Mbps of data (up to 100 [TBR] Mbps) between attached payloads and the laboratory modules for Users.

DMS will have the capability to allow prelaunch checkout, verification and validation of customer interfaces and training in DMS operations. All tools necessary for payload performance verification, over and above interface verification, are the responsibility of the customer.

2.2.3.3.2 Communications and Tracking

C&T will provide all the communications services necessary to support Space Station Freedom and payload operations. These will include command and control, audio, video, high rate data and telemetry, and communication and tracking services, both space-to-space and space-to-ground. C&T will provide transmission, reception, link buffering, signal processing and control of audio, telemetry, commands, data, video, and tracking data for all SSPEs.

The C&T system will be divided into six subsystems, each representing a major class of service or function. The space-to-space subsystem will provide communication with astronauts performing EVA, with the Space Shuttle, the OMV, the MSC, the FTS and any compatible free-flying platforms in the vicinity of the manned base. The space-to-ground subsystem will provide communication via satellites to the ground data networks and provides the data buffering required during communications loss-of-signal, satellite link unavailability, or link bandwidth limitations.

The audio subsystem will provide all of the voice communications between the crew inside the pressurized modules, the EVA crew, the crew of other manned vehicles, and compatible ground systems. The audio subsystem will be a full duplex system with conference, record and playback capability.

The video subsystem will provide all of the internal and external video capabilities on the SSFMB. The subsystem will consist of internal and external remotely controlled cameras and will include closed circuit television, video storage, retrieval, compression, graphics, and special effects capabilities. On-board distribution of video data will be analog, while video transmission to and from Earth will be digital. The subsystem will allow special area monitoring, as well as conferencing between crew locations and between crew and ground. There will be signal processor interfaces between the DMS and the video and audio subsystems.

The tracking subsystem will consist of a Global Positioning System (GPS) receiver/processor with provisions to accommodate future laser docking and radar requirements. The control and monitoring subsystem will manage all C&T resources and distribute the C&T data.

Primary communications between ground, SSFMB and platforms will be through TDRSS. Operating frequencies, data rates, modulation, and encoding will conform to the TDRSS Users' Guide, STDN 101.2, Rev. 5 (or latest approved version). Data rates in excess of the maximum Space Station Freedom capability may be transmitted as individual data streams to the ground using payload provided systems, subject to SSFMB system environmental and resource constraints.

2.2.3.4 Guidance, Navigation and Control (GN&C) System

The GN&C system provides guidance, navigation, attitude control, orbit maintenance, proximity operations, and traffic control during all mission operations. The GN&C system will establish and maintain the SSFMB and platform state vectors (e.g., position, time, velocity and orientation). State vector data, attitude, attitude rate, and other special purpose information will be provided by GN&C to support individual functions. GN&C provides simultaneous pointing information to payloads on any articulated or fixed mounting surface to accommodate pointing of instruments that have Earth, anti-Earth, solar, and stellar viewing requirements. GN&C will provide core system control and traffic management. The core system will supply attitude and orbital maintenance, support the pointing of the photovoltaic power arrays and the thermal radiators, accomplish periodic reboost maneuvers, and provide SSFMB attitude and orbital information to other systems and Users. The GN&C traffic management function will control incoming, outgoing, and SSFMB keeping traffic within the vicinity of the SSFMB. It also will control docking and berthing operations, monitor the trajectories of vehicles and objects that may intersect the orbit of the SSFMB, and support flight planning.

The core GN&C system will consist of inertial sensor assemblies, star trackers, and control moment gyroscopes (CMGs) located on the central truss. CMGs act to stabilize the motion of the SSFMB (i.e., the CMGs will compensate for the cyclical disturbance torques and will accumulate bias torques). Disturbance capability will be limited and unloaded (compensated for) by the propulsion system. The GN&C System will interface directly with the propulsion system thrusters for reboost and attitude control. Orbital state data will be provided by an on-board Global Positioning System receiver/processor via an interface with the C&T system.

2.2.3.5 Extravehicular Activity System

The EVA system will provide crew members with the capability to perform routine tasks in the unpressurized environment on and about the SSFMB. The system will support assembly, maintenance, repair, inspection, and servicing of SSFMB and User systems including the APAE.

The EVA system will consist of a number of subsystems. Central to EVA will be the Extravehicular Mobility Units (EMU). An EMU will consist of a space suit, equipment for communications and physiology monitoring, and an autonomous life support system carried as a backpack. The EVA system will include a service and performance checkout subsystem, EVA translation and mobility aids such as handrails, slide mechanisms and tethers, and EVA retrieval subsystems for servicing.

EVA lighting, generic tools, miscellaneous support equipment and lockers, extravehicular contamination detection and decontamination equipment, and systems interfaces for air lock, environmental control and life support system, thermal control and power utilities will also be included in the EVA system. These components and subsystems of the EVA system will be stowed throughout the SSFMB, with the majority of the equipment being located within the air locks. Various tools, restraints and work platforms will be located on the MSC. Mobility and translation aids will be located on the truss.

2.2.4 Environments

Experiment and associated support/accommodation equipment will have to withstand the same natural and induced environments as other Space Station Freedom systems and equipment items. Specifications for these environments are still being developed. The latest status is defined in SSFP document 30000, Section 3, Appendix A. Natural environments include: the neutral atmosphere as defined by the MSFC/J70 Model, plasma, penetrating charged particles, electromagnetic radiation, meteoroids and space debris, the earth's magnetics field, Sun-Earth thermal radiation and pressure parameters, and the earth's gravitational field. Induced environments include: ground handling and transportation; vibration, contamination; and electromagnetic interference caused by Space Station Freedom systems and other experiments. (See SSP 30249 - Space Station Electromagnetic, Ionizing Radiation and Plasma Environment Definition and Design Requirements for induced environments.)

2.2.4.1 MSFC/J70 Model of the Neutral Atmosphere

The MSFC/J70 model will be used to represent the SSFMB orbital atmosphere. The model outputs data at any time (e.g., year, day and hour) and position (i.e., latitude, longitude, and altitude) depending upon the values of the solar radio noise flux and the Geomagnetic Activity Index. Separate environmental specifications are being prepared as SSP 30425.

After Shuttle Flight MB-3 (reference the Assembly Sequence in the "Space Station Freedom Assembly Sequence Trial Payload Manifest", Release 1.0, December 9, 1988), the SSFMB nominal orbit will be at inclination 28.5° and at altitudes ranging from 180 nmi (335 km) to 250 nmi (460 km). The SSFMB nominal attitude with reference to local vertical, local horizontal (LVLH) will be with its pitch axis (the line joining the solar array alpha joints) perpendicular to the orbit plane and the roll axis (center lines of the pressurized modules) tangent to the orbit. This attitude will be held to ± 5° with knowledge of attitude to a fraction of a degree.

2.2.4.2 Penetrating Charged Particles

Radiation tolerance of electronic parts should be such as to require minimal protection for the anticipated duration of the on-orbit experiment. A guideline value of 106 Rads total dosage is suggested.

2.2.4.3 Ground Support Equipment (GSE) Design Requirements

Design requirements for GSE are specified in SSP 30000, Section 3, Part 1.

2.2.5 Coordinate Systems

2.2.5.1 Body Coordinate System

The SSFMB Body Coordinate System (SB), **Figure 2-3**, is defined as follows. The origin is located at the geometric center of the central truss. The X_{SB} axis is perpendicular to the truss. Positive X_{SB} is in the forward flight direction. The Y_{SB} axis is parallel to the truss and perpendicular to the X_{SB} axis. Positive Y_{SB} is toward starboard. The Z_{SB} axis is perpendicular to the Y_{SB} axis. Positive Z_{SB} is toward nadir. This is a rotating right-handed Cartesian system. The attitude sequence is yaw, pitch and roll around the Z_{SB}, Y_{SB} and X_{SB} axes, respectively.

2.2.5.2 Inertial Coordinate System

All SSFMB positions and attitudes as well as the celestial bodies observed by the User experiments will be measured relative to an inertial coordinate system. **Figure 2-4** shows an instantaneous snapshot of the (not-to-scale) Earth along (or parallel to) the line of intersection of the Equatorial and Ecliptic planes. An

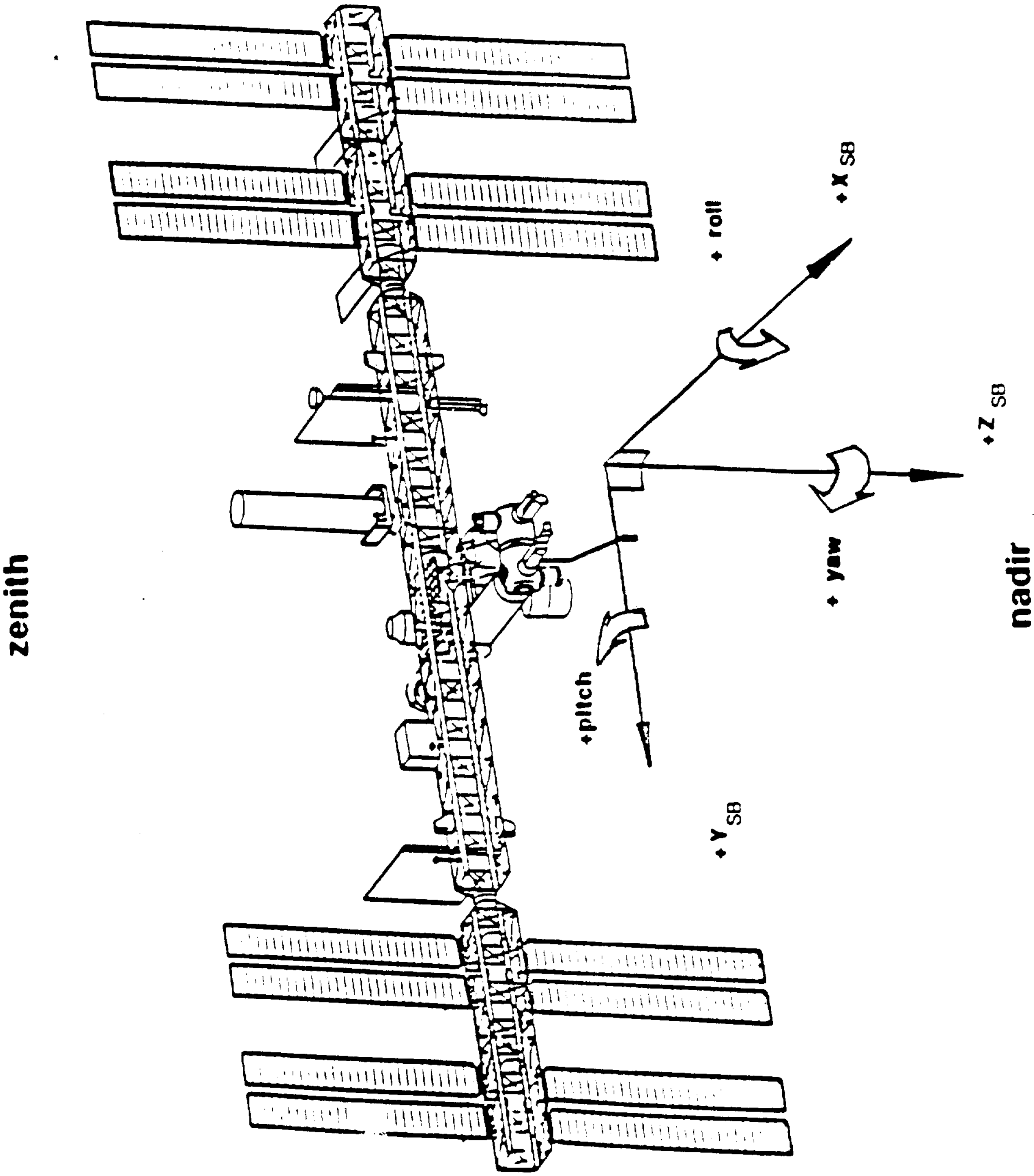


Figure 2.3 Space Station Freedom body coordinate system.

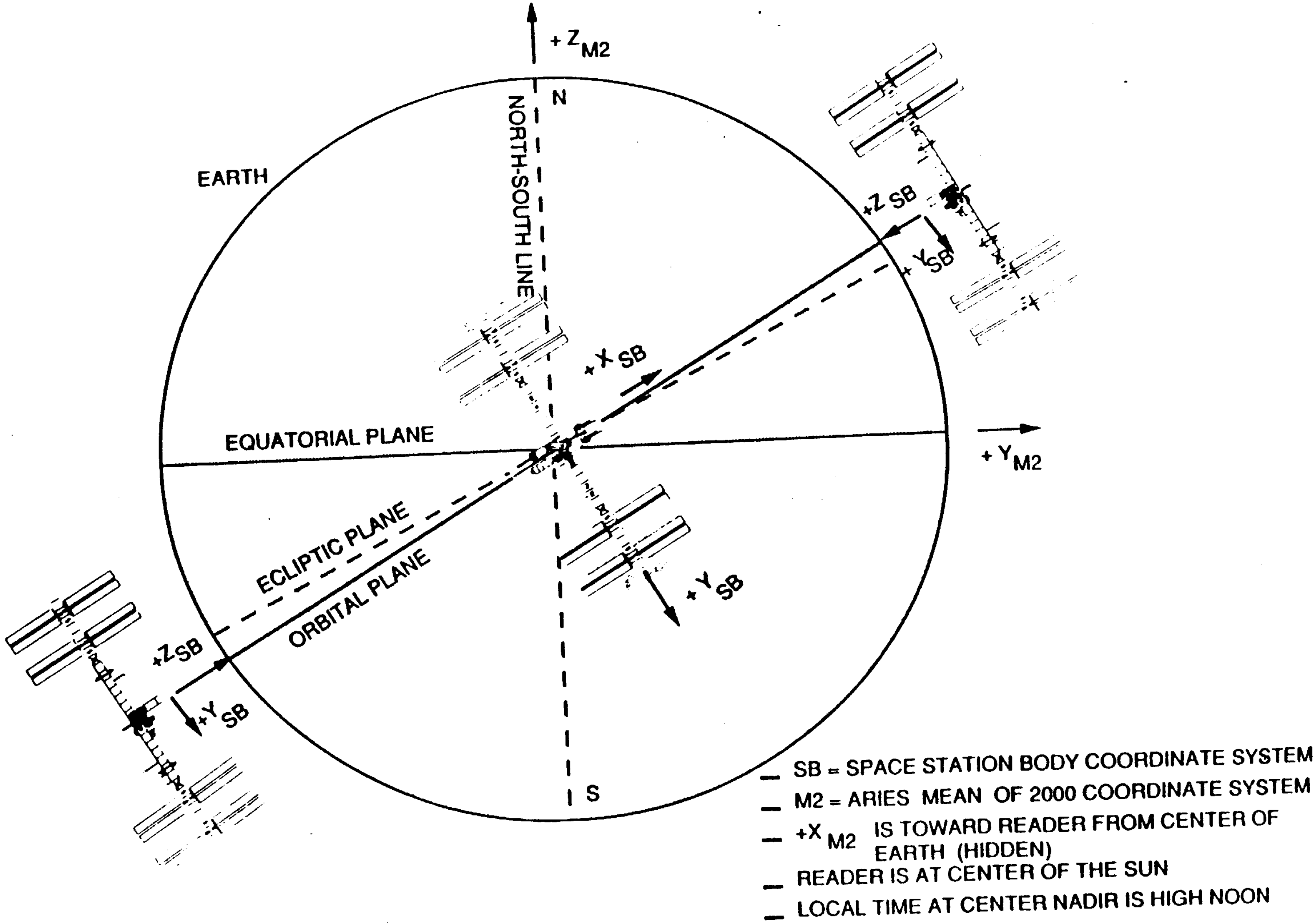
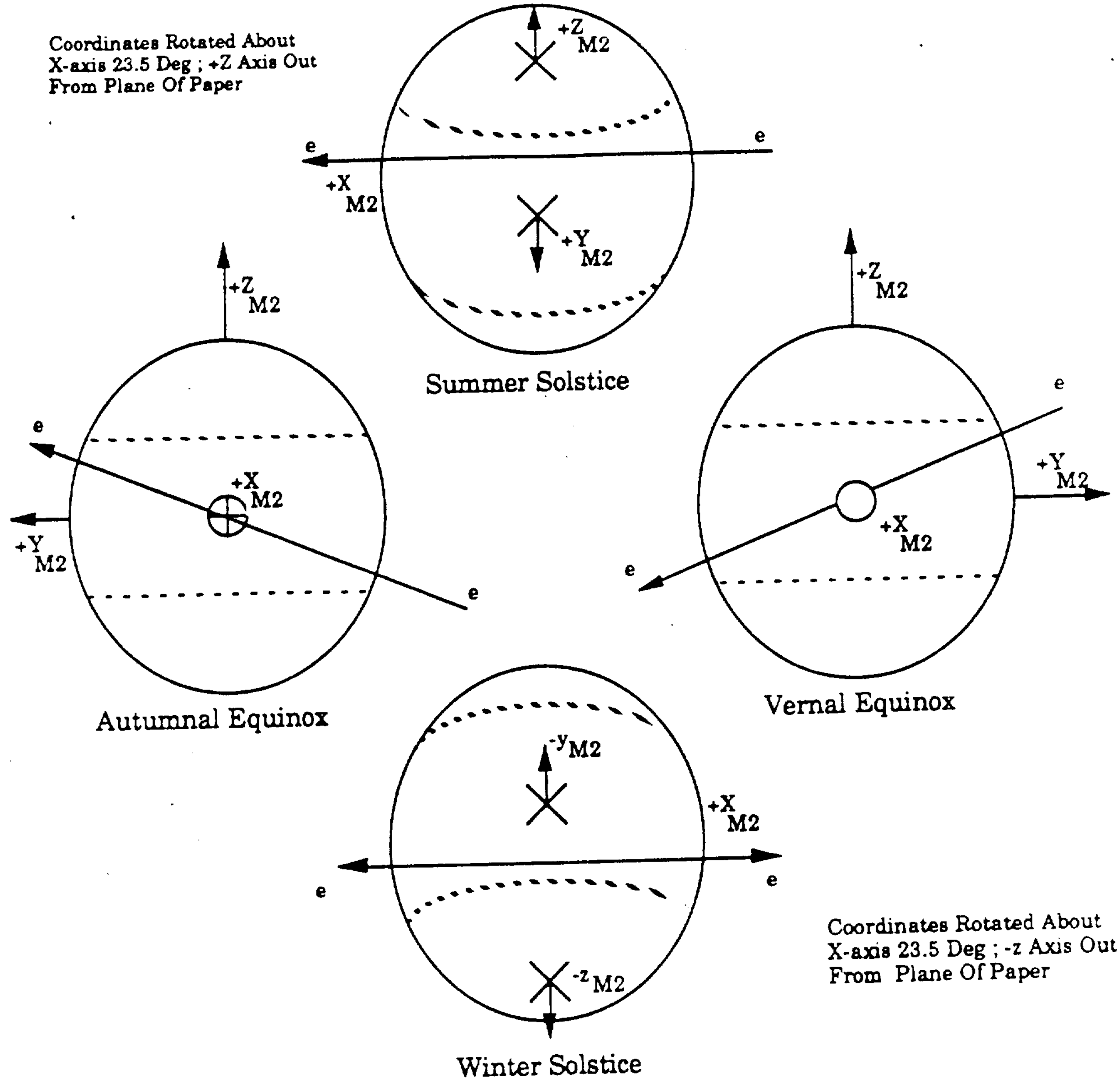
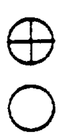


Figure 2-4. Space Station Freedom orbit-Earth-realtive motions



Ecliptic Plane (e-e) As Viewed From The Center Of The Sun For 4 Specified Seasons

Inertial Vector At Center Of The Earth Is Perpendicular To The Plane Of The Paper And :



Points Away From Reader

Points Toward Reader

Arrow On e-e Indicates Direction Of Translation Of Earth

Space Station Ground Track Falls Within The ± 28.5° Lat Band Indicated By ----------------------

M2 = Aries Mean Of 2000 Inertial Coordinates

Figure 2-5. Yearly Earth-Sun orientation observer would be at the center of the sun. Because the equatorial plane appears as a line (edge view) and because of its orientation relative to the ecliptic plane (about 23.5°) this must necessarily be the time of the Vernal Equinox occurrence.

At this instant in time, a Cartesian Coordinate System is arbitrarily defined with its origin at the center of the Earth. The axes are as shown, projected out to the Celestial Sphere. The X-axis will appear as a central point since it passes through the plane of the paper to the first point of Aries.

It is assumed that this is the year 2000 because at this precise moment the system will exactly match a standard accepted by the scientific community and also defined by the Space Station Freedom Reference Coordinate System Document (JSC 30219).

2.2.5.3 SSFMB and Earth Dynamics

In **Figure 2-4**, the Space Station Freedom orbit plane appears in an edge view on the ascending node side demonstrating its 28.5° inclination. The SSFMB itself is shown in its normal LVLH) attitude at three orbit locations: those where the times at local vertical are 6 a.m., 12 noon and 6 p.m. Note that in the SB system the positive Z-axis direction is always lying along the nadir line toward the Earth center. The positive Y-axis is always pointing in a southerly direction and the positive X-axis always points in the direction of the SSFMB tangential velocity vector.

In the three SSFMB views, the solar panels always face the sun. Relative to the SSFMB itself, these panels are rotating at the rate of once per orbit period (about 92 minutes). There are three additional primary motions as follows: First, the earth will continue its translation in the lower left direction until the Summer Solstice is reached, at which time it reverses its observed direction in inertial space and begins a translation toward the upper left through the Autumnal Equinox and on to the Winter Solstice. These positions are shown in **Figure 2-5.** Second, the Earth will continue to rotate around the North-South (or Z axis) line to the east (counter clockwise looking down from north to south) at an approximate 361° per 24 hour rate. Third, the SSFMB orbit plane will also rotate about the north-south line toward the west (clockwise looking down from north to south) at an approximate 7° (longitude) per 24 hour rate. This motion is referred to as a regression of nodes.

3.0 APAE DETAILED DESCRIPTIONS

3.1 APAE Descriptive Overview

The approach to the design of the APAE responds directly to the most common attributes of the attached payload Users - the large number of potential payloads and the diversity of their requirements. The APAE provides access to power, data and thermal resources of the SSFMB. It provides mechanical attachment and structural support for payloads for selected launch configurations.

Field-of-view from specific attached locations will be defined, including any obscurations. Certain payloads require pointing knowledge and accuracy information and others, in addition, may require pointing articulation. Some payloads may require isolation from motions caused by disturbances to the SS structure and attitude control. These diverse payload requirements are accommodated by providing a modular APAE system consisting of standard and optional items from which configurations can be selected to accommodate a wide variety of payloads constrained only by the total availability of resources.

The Space Station Freedom Program makes available to the User APAE consisting of the following major sub-elements: the Payload Attachment System (PAS); the Payload Pointing System (PPS); and the ADS.

3.2 APAE Configurations

APAE is illustrated in five typical configurations in **Figure 3-1.** In each of these configurations the accommodations provide the capability for attaching payloads of various shapes and sizes to the SSFMB central truss and for the transfer of resources for their operation. In each of these configurations the standard items are shown with the relative orientation of the SIA and PIA remaining constant. The SIA and PIA provide a standard interface between payloads and the SSFMB.

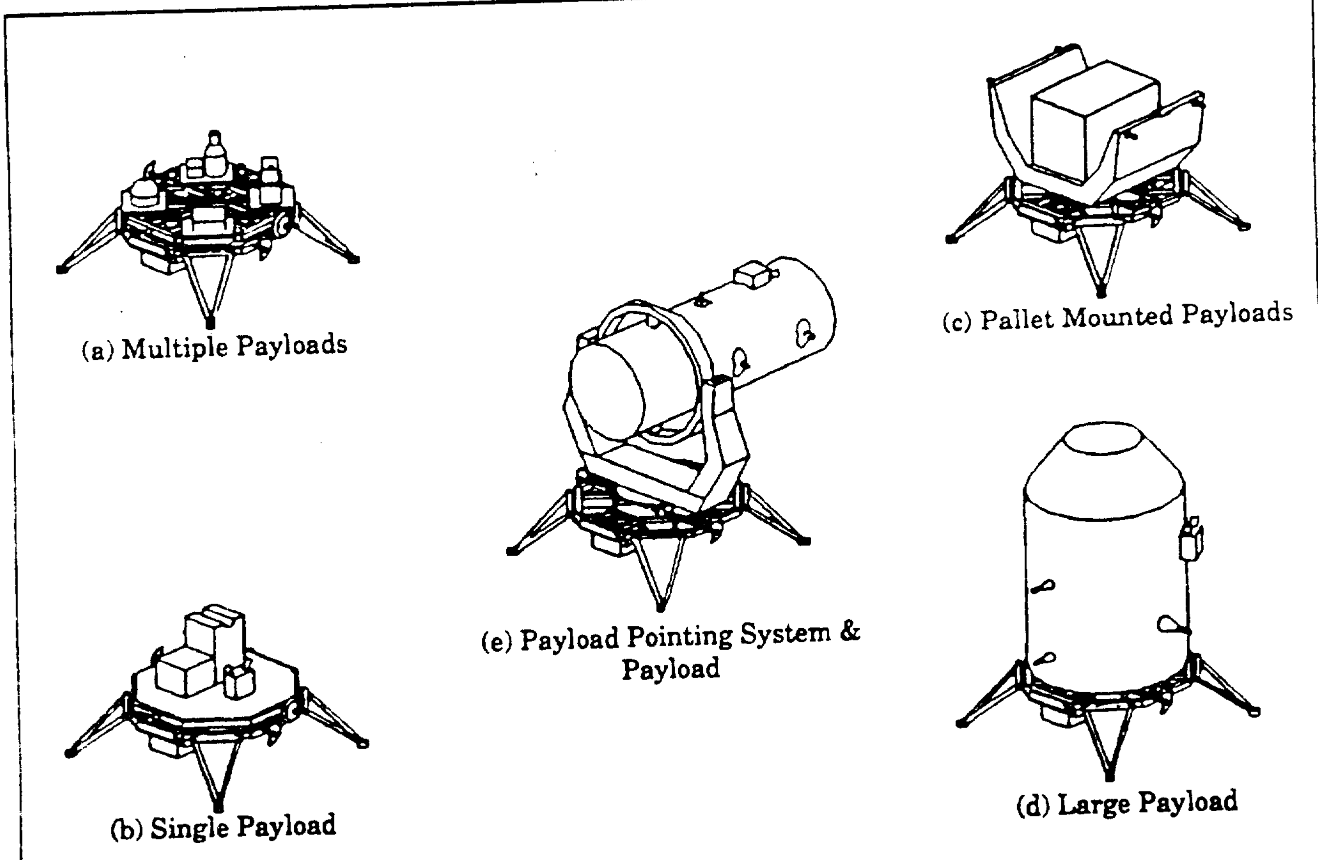


Figure 3-1. Typical attached payload accommodations

The SIA is separately transported to the SSFMB, installed on the truss structure with EVA support and connected to the utility resource ports. The SIA, which includes the capability for controlling resources, becomes a semi-permanent part of the SSFMB and remains in position when payloads are replaced. The SSM is made up of two ORUs; the System Support Module Electrical (SSME) and the System Support Module Thermal (SSMT). The SSME contains the components to obtain, control and distribute the power and data resources. The SSMT has the controls and fluids to support interfacing with the SSFMB TCS for active thermal control of the APAE and its payload. These ORUs are replaced periodically to meet availability requirements.

The PIA provides the capability for remote mating of a payload with a SIA and includes all of the active components for this mating. The PIA and payload coldplates are integrated with a payload on the ground and transported to the SSFMB as a single package.

The Deck Carrier is shown as an optional carrier for a small payload in **Figure 3-1b** or payload set in **Figure 3-1a**. As shown, each payload, or payload group, is attached to an MPA which provides the structural interface to the Deck Carrier and also provides the capability to channel resources independently to each payload in the multiple payload set. The MPA concept allows removal and replacement of any of the several payloads from the SSFMB. Each MPA is integrated with its associated payload on the ground.

The pallet shown in **Figure 3-1c** is representative of a payload unique User-supplied carrier to support the payload during launch and while on the SSFMB. In this case, the PIA is attached to the carrier during ground integration. A large payload with the PIA and payload coldplate attached directly to the payload body structure is shown in **Figure 3-1d**

Accommodation of an attached payload requiring articulation is provided by a PPS supported by the ADS or User-supplied sensors. As shown in **Figure 3-1e**, the PPS is a three axis, center-of-gravity mount, gimbal system including yokes, bearings, torquers, controls and devices to transfer resources across the gimbal axes to the payload. The ADS contains attitude sensors and reference gyros which provide pointing knowledge and error correction signals to the PPS control loop. The ADS can also be used for non-articulated payloads to provide pointing knowledge, if desired. The PPS is launched separately from the payload. Payloads are replaced on the PPS as required. The ADS is configured to be an ORU and may be physically attached to the payload.

Mission and Simulation Software is provided for each APAE sub-element. This software will reside within the SSIS Ground System and will model the APAE for training, procedure verification, and system check-out.

The APAE has a significant interface with the CSS in a pressurized area of the SSFMB. The CSS provides the facilities for operation and monitoring of the payloads and the APAE by the crew. The CSS may be a specialized MPAC in one of the pressurized modules, hosting payload unique software and supporting payload unique hardware with standard interfaces and DMS services.

3.3 Payload Attachment System and Resources at Each Attachment Site

The PAS consists of the: the SIA; the PIA; the SSMs; the Deck Carrier, and MPAs, payload coldplates and the Contamination Monitoring System (CMS). The SIA, PIA, payload cold plates and SSMs are required by all APAE users. They provide the standard interfaces with the SSFMB for physical attachment and for access to and distribution of the power, data and thermal resources. **Table 3-1** defines the standard resources available at each APAE site on the SSFMB central truss.

The MPA, in conjunction with a Deck Carrier, provides Users with small to medium payloads the structural support needed for launch. The Deck Carrier and MPA combinations can accommodate up to four payloads at a particular APAE utility port location, allowing on-orbit removal and replacement of each individual MPA-payload combination.

Table 3-1
Space Station Freedom Manned Base Resources Available to Attached Payloads

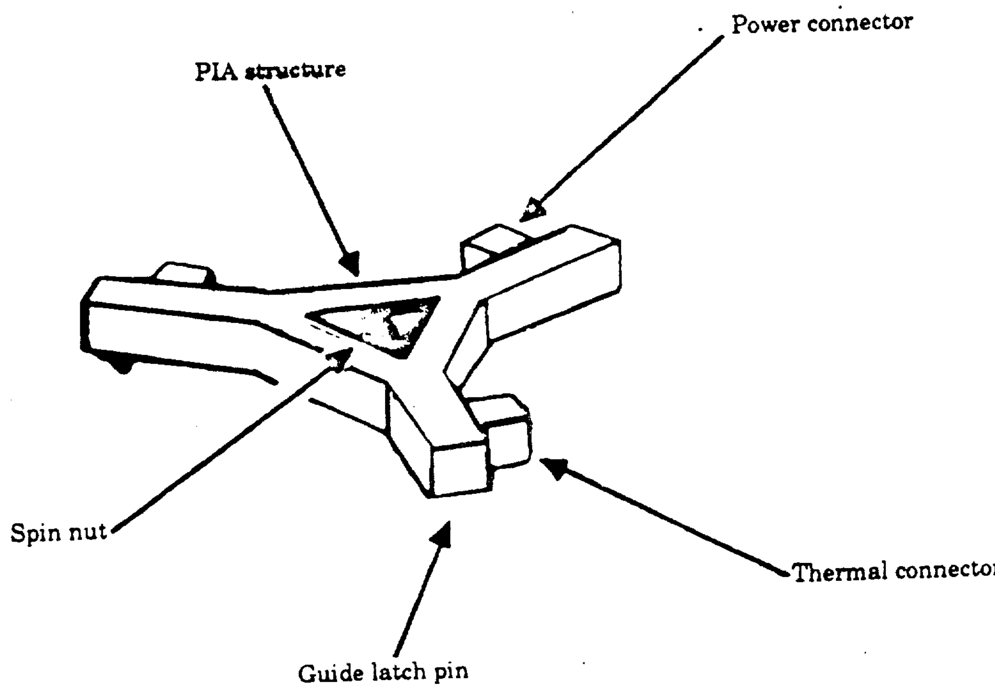
Services	Standard Capacity Each Site	Optional Capacity Each Site
POWER	• 120 Vdc - 10 kW - 5 kW	N/A
THERMAL	• Cold Plate (24°C) - 10 kW - 5 kW (PPS - 5 kW max)	N/A
COMMAND & DATA HANDLING	• 100 Mbps Hi-rate data • 10 Mbps LAN • Real time Cmds • Data return • Storage & buffering • Processing • Video	N/A
MONITORING DATA	• Orbit Ephemeris	• Contamination monitoring - Total pressure - Molecular species - Molecular deposition - Particulate deposition • Attitude knowledge • Payload pointing

The CMS provides Users with the option of monitoring the local payload environment. The CMS also provides alarms should the local contamination levels exceed predetermined values.

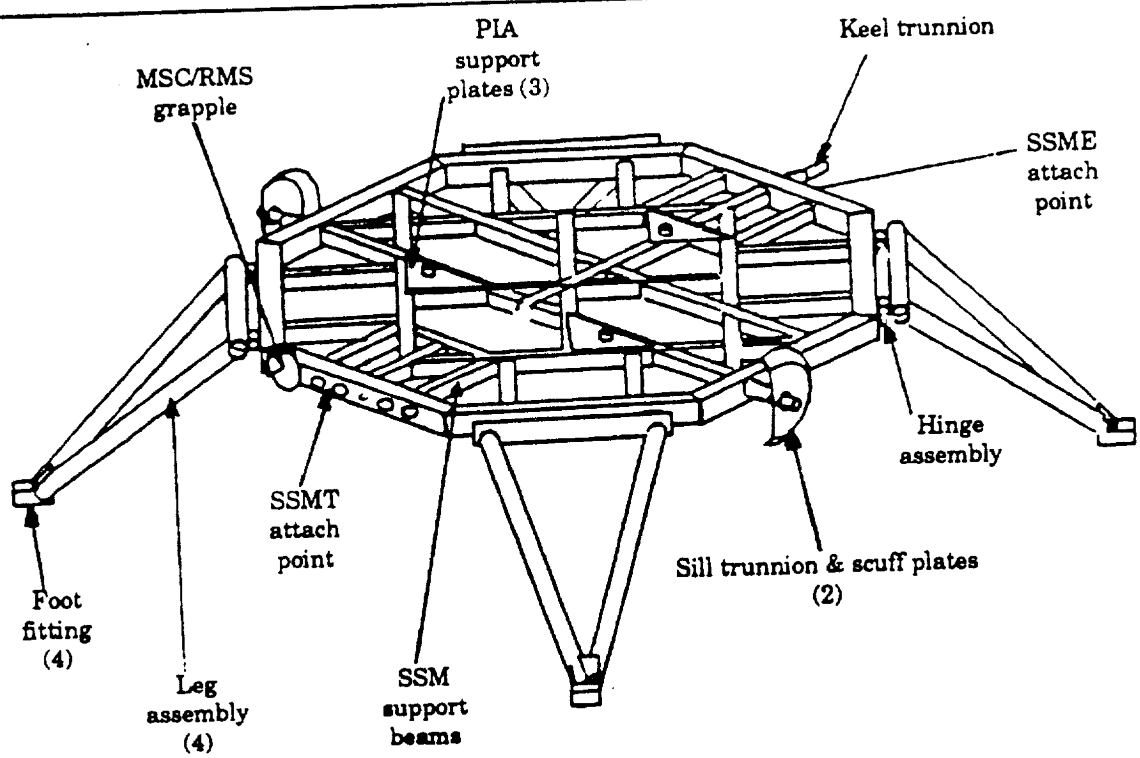
3.3.1 Station Interface Adapter

Figure 3-2 illustrates the configuration of the SIA which provides the structural and resource interface between the SSFMB and the payload/equipment mounted outboard of it. In addition to these interfaces accommodations are also provided to support the SSMs, electrical and thermal, which provide the conditioning and distribution of resources to the payloads. The SIA to truss interface is a 4-point suspension on 16.4 feet (5 meter) centers. The SIA height above the truss is 5 (TBR) feet (1.82 [TBR] meters) and the SIA mounting plate is a 13 (TBR) foot octagonal (across flats) (3.94 [TBR] meters).

The SIA can be mounted on the top, bottom or back face of the central truss depending on payload orientation requirements and MSC restrictions. Power and data payload interfaces are provided through both a primary and a redundant connector. The SIA also includes hand holds for astronaut stability and a grapple attachment for transport on the SSFMB by the MSC. It interfaces mechanically to the PIA by means of a power screw and three guide/latch pins.



Payload Interface Adapter — PIA



Station Interface Adapter — SIA

Figure 3-2. Payload mechanical attachement interfaces.

3.3.2 Payload Interface Adapter

The PIA, illustrated in **Figure 3-2**, is a "Y"-shaped box structure 6 inches (15 cm) thick. The ends of the "Y" are at a radius of 36 inches (0.9 meters). This structure provides the standard interface between any attachment of a large, directly supported payload as shown in the exploded view in **Figure 3-3** or optional support structure such as a User-supplied pallet mounted payload as shown in **Figure 3-4**; or Deck Carrier and the SIA. The PIA also provides the active interface for power, data and thermal resources .

3.3.3 System Support Modules

The SSMs consist of the SSME and SSMT. The SSMs provide control and distribution of power, cooling fluid, data and communications to the payload. The SSMs are mounted to the SIA and are available for payload use in any of the defined configurations shown in **Figure 3-1**. The SSM structures are capable of supporting all loads associated with the SSM equipment and of transmitting those loads to the APAE structure. The SSMs are ORUs.

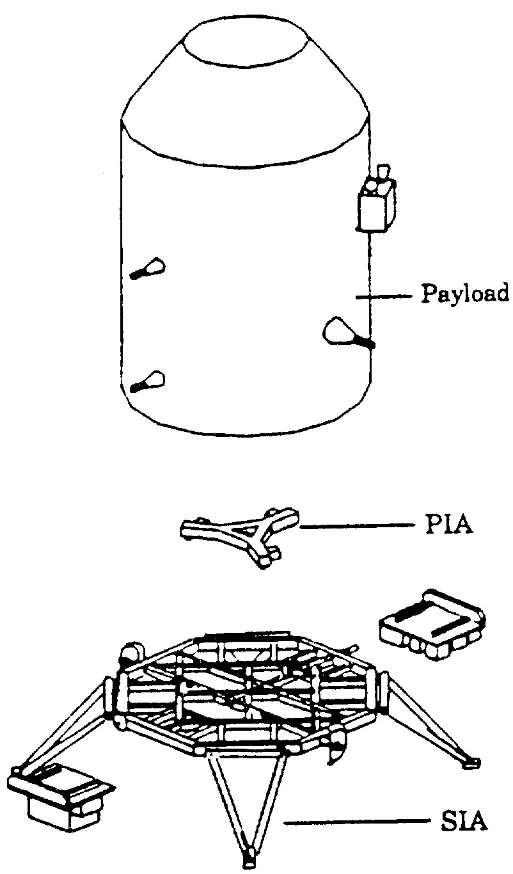


Figure 3-3. Large, self-supported payload.

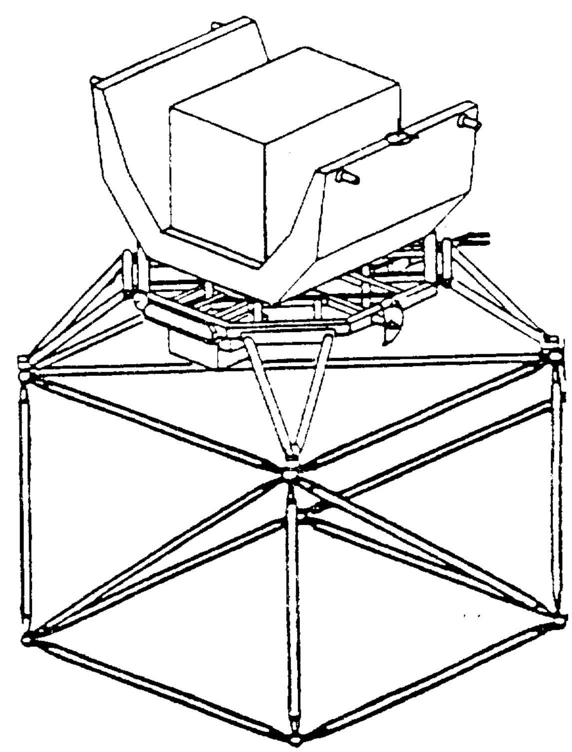


Figure 3-4. User-supplied, pallet mounted payload.

3.3.4 Deck Carrier

During launch on the NSTS, the Deck Carrier spans the Space Shuttle cargo bay, mating with keel and sill trunion mounts, to provide the payload and associated APAE with structural support. It is an optional means of accommodating and transporting payloads of limited size. Its configuration is shown in **Figure 3-5**. The Deck Carrier also provides the necessary interfaces for the structural accommodation of the PIA and up to four (TBR) Multiple Payload Adapters.

3.3.5 Multiple Payload Adapter

The MPA is an optional item of the APAE which provides the capability to support a single payload housed in single or multiple boxes. In addition, up to four compatible payloads can be mounted at a single SIA mounting location where one or more of the payloads can be replaced without removing the others. This may be done by EVA or robotically. The MPA, when installed on a deck carrier, provides transportation support and on-orbit structural support for its associated payload and transmits all loads to the Deck Carrier. Each MPA will interface with a Standard Interface Connector (SIC) providing the necessary power, data and thermal support required from the SSFMB.

Attachment of multiple small payloads together with their associated MPAs is shown in an exploded view in **Figure 3-6**. **Figure 3-7** is an exploded view illustrating the attachment of a single small payload to the deck carrier (no MPA utilized). Resources for payloads of this type will typically be provided through the Resource Connectors normally provided for the MPA. Each MPA transfers up to 5 kw of power along with the standard data and thermal resources (See **Table 3-1**) to the payload through the interface provided by the SIC to the Deck Carrier.

Figure 3-8 depicts the assembled configuration as it would appear when secured to the SSFMB.

3.3.6 Grapple Fixture

A power and data grapple fixture, similar to those used in the Shuttle cargo bay for removing and installing payloads, provides the primary structural interface between the APAE/payload structure and the SSFMB robotics, the MSC and the FTS. The grapple fixture can have the capability of providing limited power and data for: survival heaters during transportation; mechanism activation; monitoring critical functions for a limited time; and similar applications.

3.3.7 Contamination Monitoring System

The CMS for the APAE monitors and measures contamination levels at or near attached payload locations and provides a status and warning system to alert Users of changes in contamination loads that could degrade equipment, affect data accuracy and/or require changes in operational procedures. In addition to providing status data for display at the CSS or on the ground, the CMS will have the capability to provide data to the PAS Controller Multiplexer/Demultiplexer (CMDM), so the PAS CMDM can warn and initiate protective measures by the attached payload(s). Threshold Levels for the PAS CMDM will be set through negotiations between the users and the SSFP.

Standard contamination monitoring capabilities of the CMS will include total pressure, molecular species, molecular deposition, and particulate deposition. The current CMS measurement sensitivities are:

Total pressure	2×10^{-10} to 2×10^{-3} Torr
Molecular species	8×10^{-11} to 8×10^{-4} Torr and 1 to 150 AMU
Molecular deposition	4.4×10^{-9} grams/cm^2
Particulate deposition	3.5×10^{-8} grams/cm^2

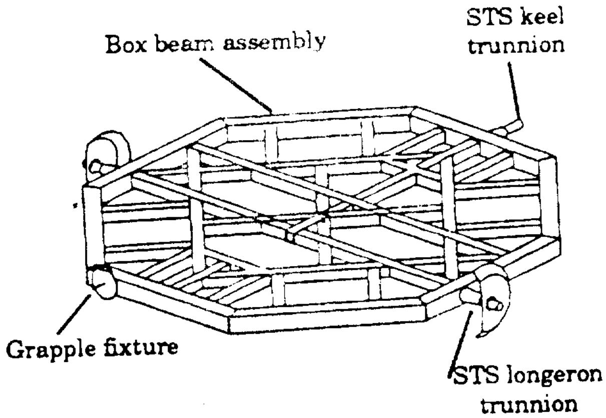


Figure 3-5. Deck Carrier assembly.

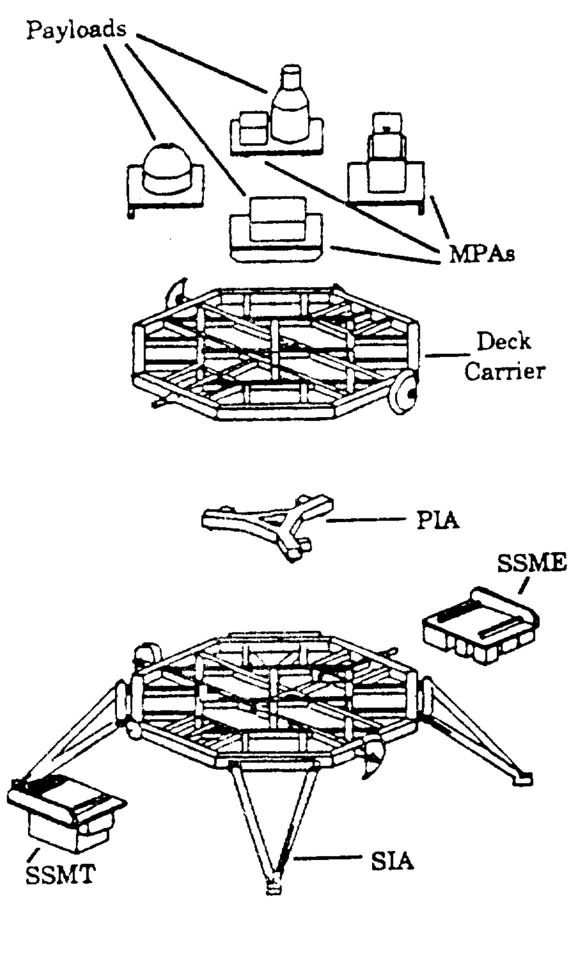


Figure 3-6. Multiple payload/Deck Carrier configuration.

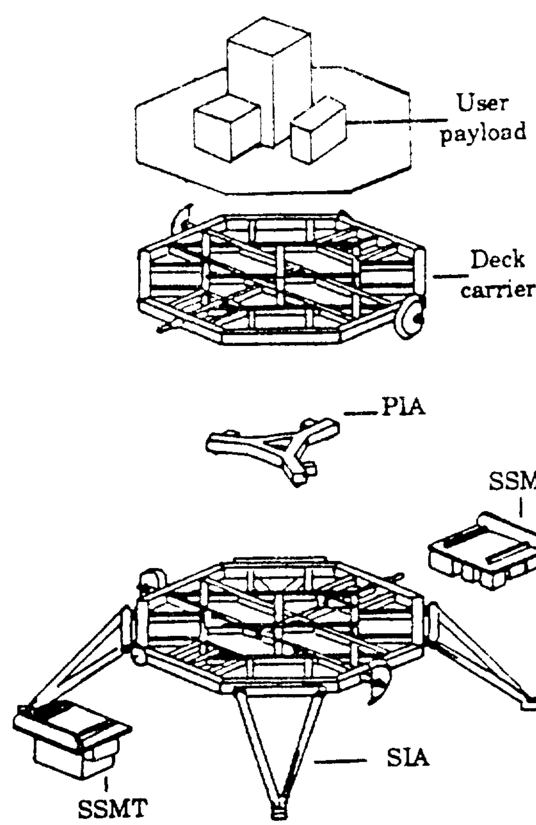


Figure 3-7. Single payload/Deck Carrier.

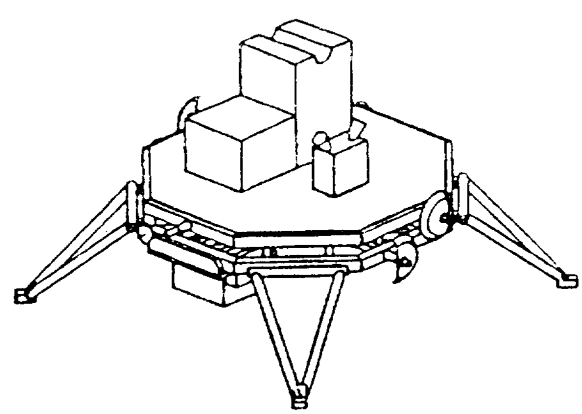


Figure 3-8. Single payload/Deck Carrier configuration (assembled view).

In the current design, measurements are performed by detecting substances at or through the measurement unit itself. Thus, the mounting location is critical. No field-of-view measurements, spectral irradiance, or molecular column density measurements are possible.

3.4 Payload Pointing System

The PPS provides articulated pointing control for attached payloads relative to designated targets and the capability of slewing these payloads to acquire, reacquire and track such targets as well as to compensate for any SSFMB motion. The PPS provides a standard interface for payload attachments and the transfer of power, data and thermal utilities across the gimbal system.

Remote and EVA actuated attachment devices are also provided for on-orbit connection to payloads and interfaces with the MSC, the FTS and EVA equipment tools. The concept for accommodating an articulated payload is indicated in **Figure 3-9**. The PPS is a three-axis (i.e., azimuth, elevation, and cross elevation) gimbal system. The inner ring will accommodate a 9.8 feet (3 meter) diameter payload. The PPS is designed for a payload with a center-of-gravity mount with an 8.2 foot (2.5 meter) to base swing-through clearance, (radius from PPS ring center to base of yoke). Payloads with masses up to 13,200 lbs. (6000 kg) and mass moments of inertia up to 11,400 (**TBR**) kgm^2 can be accommodated on orbit.

Payloads not compatible with a center of gravity mount can also interface with the PPS in a center of gravity offset mode, so long as the envelope falls within base swing-through clearance limits. Such payloads will experience some degradation in pointing performance. The performance of the PPS will also be limited by the magnitude and spectral properties of the base motion input from the SSFMB central truss assembly as well. Pointing capabilities are shown in **Table 3-2**. The slewing capabilities of the PPS depend on the moments of inertia of the PPS supported payload. The current requirement is to slew 90° in five minutes.

TABLE 3-2

Attached Payload Pointing Capabilities (±3 sigma)

	KNOWLEDGE	ACCURACY	JITTER	STABILITY
Pointing Payloads	36 ARC SEC (PEAK TO PEAK) FOR 1 SEC.	60 ARC SEC (PEAK TO PEAK) FOR 1800 SEC.	15 ARC SEC	30 ARC SEC
Other Payloads	0.25 DEG	5.0 DEG (WITH RESPECT TO LVLH)	TBD	TBD

The PPS structure and its associated support equipment provide load paths to support the PPS during transport by the Shuttle and MSC. The PPS will be configured such that it can be launched fully assembled not including the associated attached payload.

The PPS can also utilize reference attitude data developed by a sensor that is integral to the attached payload. The payload sensor data can be used in a direct mode or in conjunction with the ADS. A functional block diagram of the PPS is provided in **Figure 3-10**.

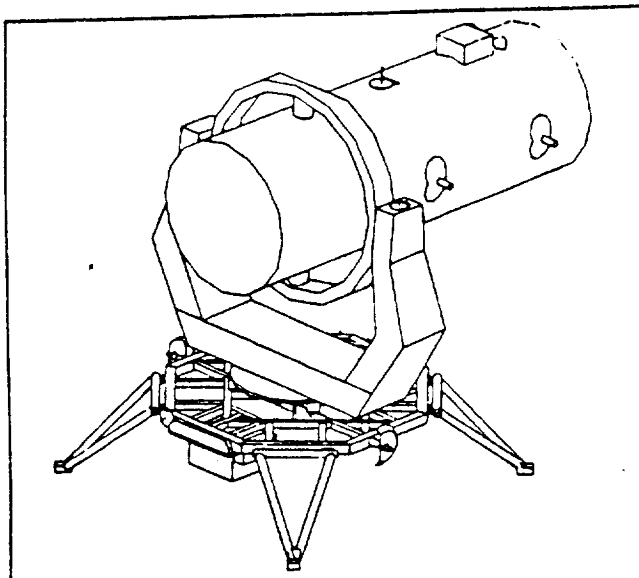


Figure 3-9. Payload & Payload Pointing System.

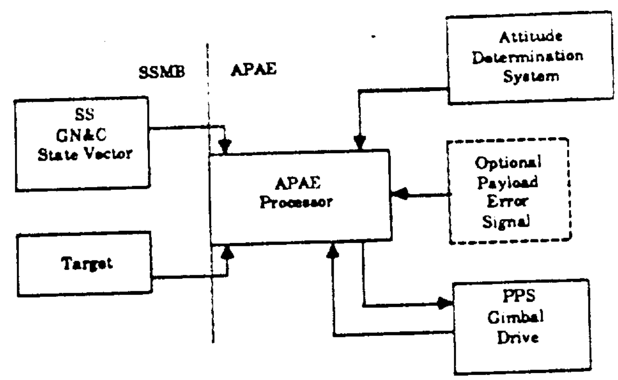


Figure 3-10. Functional block diagram of PPS.

3.5 Attitude Determination System

The ADS provides precise, high-bandwidth, three-axis attitude reference data for use by attached payloads. It has the capability of utilizing either star, Sun (TBR), Earth (TBR), or payload sensors as references for attitude determination and provides a standard, stable interface for attachment to either payload, or the PPS.

The ADS is normally attached to a payload and measures the orientation (attitude) of the payload with respect to a coordinate system defined by the Vernal Equinox and the Earth's spin axis.

The ADS measurements are available to attitude sensitive payloads for image compensation, for example, and to the PPS to control the orientation of a payload. A simplified block diagram of the ADS is shown in **Figure 3-11**

The ADS consists of: an alignment reference (an optical cube); a cold plate to which inertial and optical sensors are mounted; an inertial sensor (gyro); optical sensors selected from any of the star, Earth, and Sun sensors; data communications equipment; a power supply; and an Embedded Data Processor (EDP).

The complement of required ADS attitude sensors will vary as a function of the requirements and location of the applicable payload. The required sensor complement is dependent on the payload target selection, pointing accuracy requirements, and field-of-view constraints.

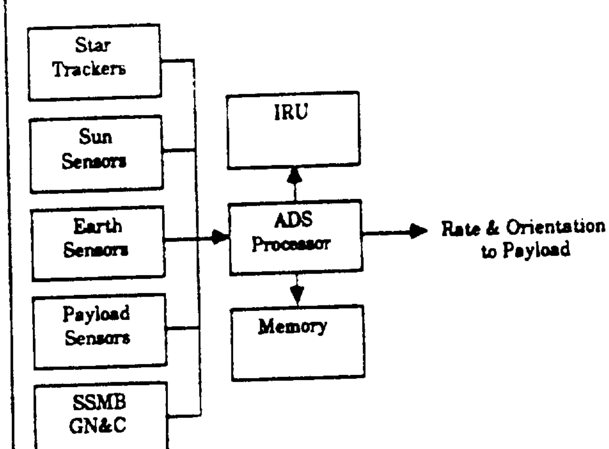


Figure 3-11. Functional block diagram of ADS.

4.0 PAYLOAD INTERFACES AND ACCOMMODATIONS

4.1 Structural/Mechanical

4.1.1 Self Supported Payloads

Payloads not using the APAE Deck Carrier (**Figures 3-3 and 3-4**) must provide their own launch structure including provisions for integrating the PIA to permit payload attachment to the SSFMB. In addition, APAE provided coldplates for interfacing with the SSFMB and APAE ATCS must be integrated with the payload.

4.1.2 Payloads Supported on a Deck Carrier

The APAE Deck Carrier is designed to carry multiple small-to-medium sized payloads or a single payload into orbit. The limiting criteria is the weight x CG offset moment, which is restricted by the reaction capability of the NSTS keel to a range between 75,000 and 100,000 inch-pounds. As a practical limit, the total payload weight to be accommodated by the Deck Carrier should be less than 3500 lbs (1587 kg).

The Deck Carrier provides two general types of accommodation. In one type of accommodation (**Figure 3-6**), up to four (**TBR**) compatible, small to medium sized payloads, are secured to the Deck Carrier through the use of MPAs. The MPA provides the structural interface to the carrier, the thermal interface to the ATCS, and power and data interfaces. This multiplexed resource arrangement also facilitates replacing payloads on orbit without disturbing the operation of the other carrier supported payloads. The second type of accommodation for a large payload (**Figure 3-7**), uses hard-mounts to the Deck Carrier using standard fasteners. The Deck Carrier incorporates a PIA that serves as the interface to the SSFMB SIA. The removal from the STS cargo bay, transport to the installation site on the SSFMB and the mating to the SIA are conducted remotely without the need for EVA.

The Deck Carrier imposes only one additional constraint on payloads that is not otherwise imposed by the STS or the SSFMB. Since the Deck Carrier is a flat frame (approximately 6 inches [15 cm]) and because the PIA interface is on the rear side of the Deck Carrier, envelope penetrations below the interface plane must be negotiated with the SSFP.

4.1.3 Multiplexed Payloads

The APAE Multiple Payload Adapter (MPA) is primarily used with the Deck Carrier as described in paragraph 4.1.2. The standard size for a MPA plate is 5 (**TBR**) feet (1.55 meters) x 3.4 (**TBR**) feet (1.04 meters). The payload is mounted to the MPA plate, which is in turn mounted to the Deck Carrier via a SIC. This connector passes all electrical data, power and thermal resources through to the payload and is the primary structural mount for the payload assembly. A standard interface is provided on the SIC for the remote assembly and disassembly of the MPA via the MSC or the FTS. Transportation of the MPA/Payload is provided by the Mobile Transporter to and from the STS.

4.1.4 Thermal Control

Two standard size thermal cold plates (5 kW and 10 kW) will be provided for payload use. These cold plates, compatible with the MPA, Deck Carrier, PPS and PIA can be located on the payload in accordance with the Users design. The interface between the cold plate and the resource connections on the APAE hardware to accept fluid connectors is common throughout the SSFMB. All heat generated by the payload is transported to the ATCS for radiation by the central radiators. Passive heat rejection, if required, will have to be approved by the payload integrator on an individual basis since the radiative view factors required for this assessment are unique to each payload.

4.1.5 Articulated Payloads

A PPS is available should a payload require pointing or positioning to accuracies greater than that provided by the basic SSFMB control system. The PPS is configured to accept payloads up to three meters in diameter which are supported via a standard structural interface. This interface also accommodates those connections required for the transfer of resources available from the SSFMB for data, power and thermal control. The payload mounted segment of this interface structure is expected to be provided by the SSFP. Master tooling to assure the proper installation of the interface structure to the payload will be available.

4.1.6 Payloads Requiring Attitude Knowledge

An ADS is provided for articulated payloads and fixed payloads requiring attitude knowledge greater than that provided by the SSFMB. The ADS is secured to a platform similar in configuration to that of an MPA providing both the structural and resource interfaces required for operation when attached to a PPS accommodated payload. A similar mounting would be required when the ADS is secured to a user provided support structure. For those payloads mounted to a Deck Carrier, the ADS would be secured directly to the MPA along with the payload.

4.1.7 Deployable Payloads

The APAE design does not impose restrictions on deployable structures. Operational restrictions will include avoidance of the SSFMB (e.g., solar arrays, radiators and communications antennas) which may be mounted in the vicinity. All payloads to have re-stow capability and the capability to jettison deployed items in the event of failure of the stowage mechanisms. Deployable payloads will have the most clearance if deployed along or against the velocity vector (± X axis) or up to zenith (- Z axis) if mounted on top of the SSFMB central truss or down to nadir (+Z axis) if mounted on the bottom. Payloads should avoid the need to deploy along the Y axis.

The APAE itself imposes no deployment envelope restrictions except into the APAE equipment itself. (Reference Figure 4-1 for typical payload locations on the SSFMB central truss.) The front face of the truss is reserved for the MSC and cannot be used for mounting payloads.

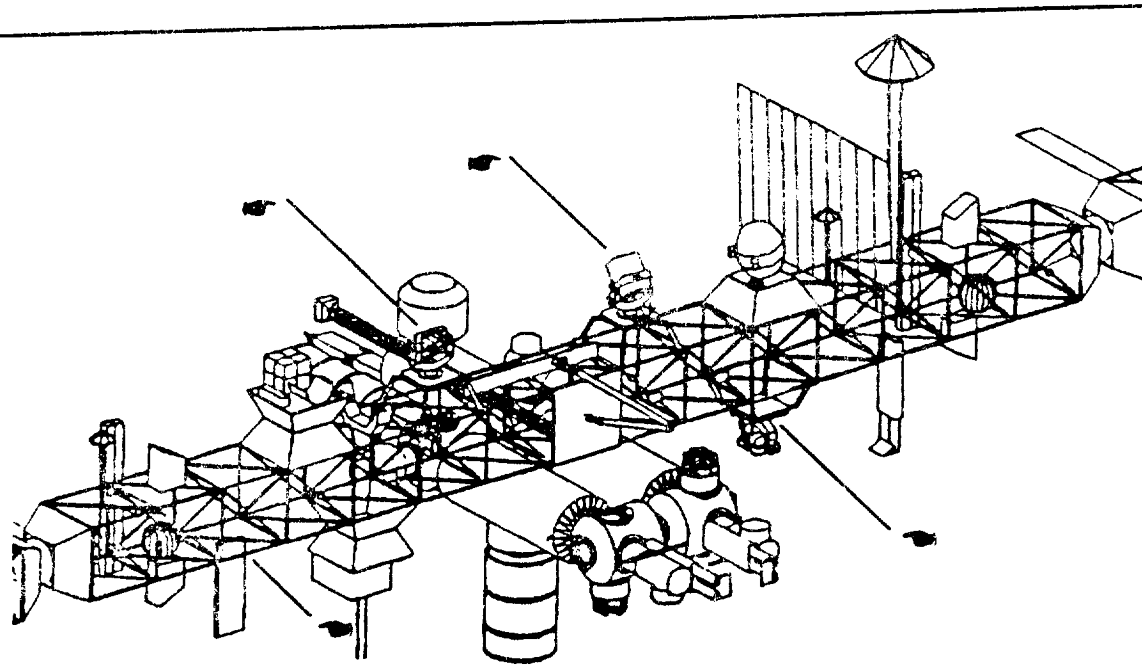


Figure 4-1. Typical payload locations of the SSMB central truss.

4.2 Data Management System

4.2.1 Subsystem Description

The DMS provides:

- Capability to command and control payloads and the APAE
- Transfer of high rate and video data from payloads to the ground via the C&T system
- Conversion of analog housekeeping data to digital format as required
- Distribution of commands and data to payloads and APAE
- Interfaces with the DMS for transmission of standard rate data for on-board storage, display at the CSS, and/or to the ground
- Interface to the CSS for display of video services and high rate data via User equipment
- Interface for timing and frequency standards as required by payloads
- A host for the APAE software.

All commands/data to and telemetry/data from payloads will be transmitted to/from the Ground Station or CSS via the SSFMB DMS. The architecture of the DMS consists of a number of global Local Area Networks (LANs), to which are connected Mass Storage Units (MSUs), MPACs, a family of Standard Data Processors (SDPs), and data handling interface equipment. SSFP global networks will carry SSFMB engineering and housekeeping data. The payload global network carries low rate (10 Mbps) payload commands and low rate data to and from User payloads. User and SSFMB engineering data is separated to help insure safe and interference-free operations. High rate data and video payloads are serviced by dedicated links connecting them to the C&T and the CSS via DMS high rate data links.

The APAE/DMS architecture, illustrated in **Figure 4-2**, uses the basic system building blocks. The primary component of the data system is the CMDM providing the User interface. The components are modules within the CMDM that provide payloads with a standard physical and functional interface for high-rate data and video transmission.

The CMDM is addressable through the SSFP payload network. The CMDMs are configured as required for single payloads, multiple payloads, or payloads with pointing systems and are distributed among the APAE ORUs. The architecture allows modular change and growth.

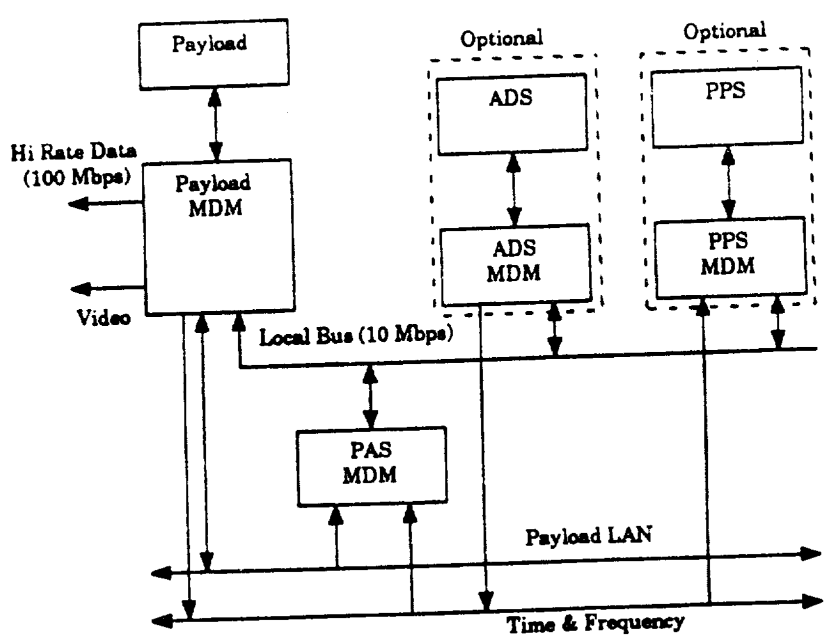


Figure 4-2. APAE/DMS functional block diagram.

Standard data rates of up to 10 Mbps are supported by the DMS. Direct channels from the payload through the CMDM to the C&T provide for data rates up to 100 Mbps.

4.2.2 Subsystem Standard Interfaces

The APAE DMS is capable of supporting a variety of payload interfaces. These interfaces enable payload data to be buffered and then distributed to data storage, to an MPAC or CSS for viewing and manipulation or to a ground station. The following is a list of interfaces available to each payload as an APAE DMS service:

- Direct memory access interface at a throughput of 12.5 Mb/sec.
- IEEE-488 parallel interface
- RS422/449 serial interface
- RS232 serial interface
- RS170 video interface
- 100 Mbps optical interface
- 5V discrete input/output interface
- 28V discrete input/output interface
- Analog (-5.0V to +5.0V) input/output interface
- IEEE 802.4 optical token passing bus
- IEEE 802.5 optical token ring (FDDI)
- MIL-STD-1553B command/response bus

4.3 Electrical Power System

The EPS: provides interfaces with the SSFMB EPS; distributes, controls and manages power to payloads and APAE; provides payload and APAE circuit protection and fault detection/coordination; monitors status for element equipment; provides a capability to accept NSTS and/or MSC/FTS power; converts SSFMB power to power types required for APAE; and regulates the converted power.

The APAE/EPS, shown in **Figure 4-3** utilizes the SSFMB Power Distribution and Control Assembly (PDCA) to provide normal operating, standby, and survival power for payloads and APAE. The PDCA provides up to 12 kW of 120 volt direct current power to each SIA ,10 kW of which is available to the Users. APAE housekeeping and survival payload heater power is provided by separate 2 kW feed from the PDCA.

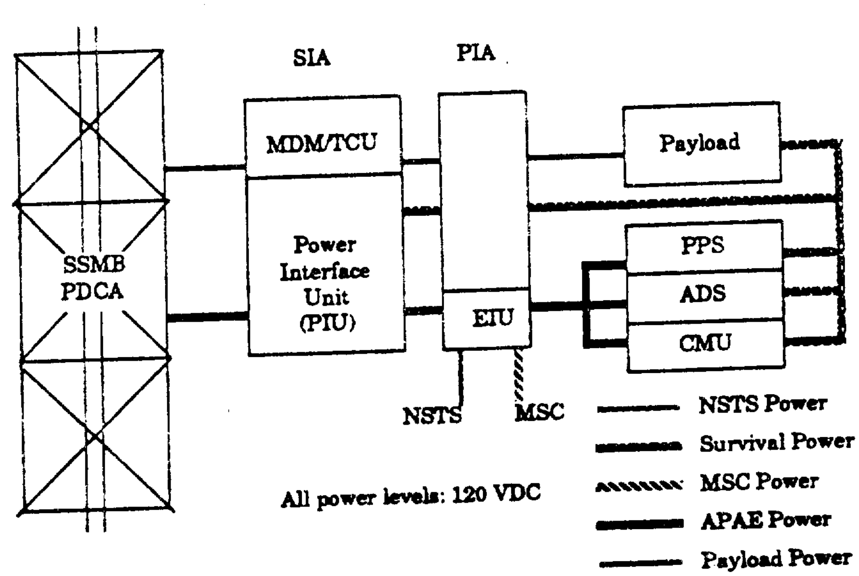


Figure 4-3. APAE/EPS functional block diagram.

The APAE Power Interface Unit (PIU) provides the electrical power for both payloads and APAE. The PIU also provides required fault protection, bus switching, monitoring functions for payloads and APAE. The PIU is controlled by the PAS MDM. The Electrical Interface Unit (EIU) provides the interface between the APAE EPS and the NSTS and/or the MSC/FTS. The EIU also provides the distribution function for the survival heater power to APAE and payloads. Survival heater power will be 120 Vdc.

The SSFMB electrical power characteristics are defined in SSP 20482. Electromagnetic compatibility/electromagnetic interference limits are defined in SSP 30237, and grounding requirements are defined in SSP 30249. Electromagnetic radiation, ionizing radiation and plasma environments are defined in SSP 30429.

4.4 Thermal Control System

The function of the TCS is to maintain specified temperatures, thermal gradients and rates of temperature change for the payload interfaces and the APAE. Supply heaters are used to maintain safe temperatures at payload interfaces and for equipment during low power or non-operating conditions. The TCS provides for heat acquisition from attached payloads and APAE, transports heat to the SSFMB thermal bus and monitors fluid loop pressures, flow rates and critical interface temperatures. It also provides protection from, and control of, ambient environmental heat fluxes and sinks.

The APAE/ATCS is shown schematically in **Figure 4-4**. For each APAE set, one two phase APAE loop will interface with the central thermal bus via heat exchangers. The APAE/ATCS is a single-string fluid loop having redundant pumps, control valves, and sensors. Two-phase cold plates collect heat from the payload and the SSME and transfer the heat via the loop to core SSFMB heat exchangers. Direct fluid flow through an instrument with a built-in cold plate to the SSFMB heat exchangers via the APAE loop is allowed. These heat exchangers are coupled to the SSFMB 70°F (21°C) and 35°F (2°C) loops. The low temperature loop provides subcooling for the APAE two-phase loop and a lower interface temperature for payloads .

The fluid loop is completed with the PIA and SIA being coupled with fluid connects/disconnects. After the fluid lines are coupled, the loop is charged by releasing the ammonia from an accumulator. Once the loop is charged, payload operations may begin.

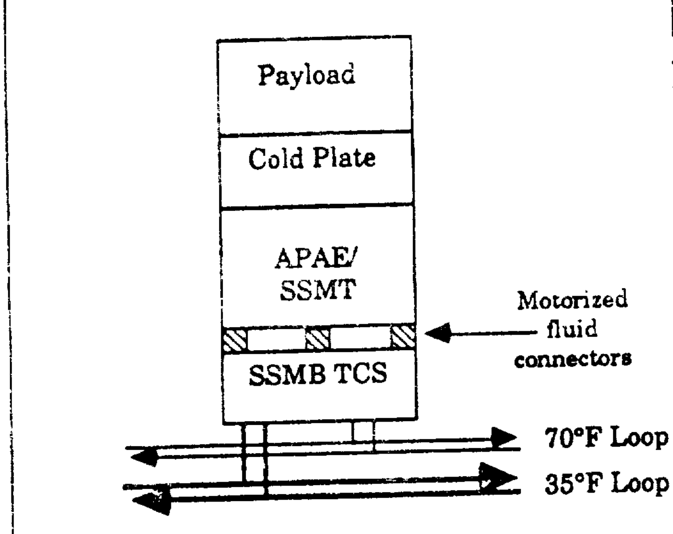


Figure 4-4. APAE/TCS functional block diagram.

The APAE is equipped with survival heaters controlled by thermostats as well as standby heaters which may be controlled through the DMS. Survival heater power will be supplied to a payload. These heaters may be used during launch on the Shuttle and during transfer via the MSC.

Conductive coupling is required between the payload and its cold plate necessitating the use of interface fillers and procedures which can best be accomplished on the ground. Mating is accomplished on the ground. The payload cannot be separated from its cold plate in orbit. Fluid disconnects allow removal of individual payloads in orbit without demating the payload from its cold plate and allow the cold plate to be selected to accommodate the heat rejection requirements of an individual payload. Several standard cold plate sizes are planned.

The APAE/PTCS employs thermal coatings, insulation, low conductance materials, and auxiliary radiators as required to assist the active TCS in meeting APAE thermal requirements.

Each APAE TCS is capable of transporting a total of 10 kW payload heat plus 2 kW of APAE housekeeping heat, while maintaining the payload coldplate interface temperature at 75°F ±7°F (24° ±4°C). This total capability is shared in cases of multiple payload support.

4.5 Robotics

The primary payload interface to the Space Station Freedom robotics systems, the MSC and the FTS, involves the use of the SIC and the standard end effector grapple which is used on STS payloads. The grapple is designed to be grasped by the MSC or FTS arms and allow transport of items around the SSFMB. The SIC is designed to attach or disconnect ORUs using a screw actuator which is driven by either the MSC or FTS arm. A special end effector tool, similar to one used by the Solar Max repair crew, inserts a driver into the top of the SIC and sequentially makes a structural connect/latch, then drives electrical and thermal connectors into place.

All payloads must also be EVA compatible since EVA is the backup mode for on-orbit robotic operations. Payload general design criteria are defined in NASA-STD-30000, Vol. IV, Section 3.0.

5.0 GROUND OPERATIONS

5.1 Overview

This section identifies and defines the responsibilities of the User and the SSFP for ground processing operations. The material covers activities at the User site, Payload Integration (PI) Centers, and the launch post-landing sites.

Operations of the SSFMB will commence with the first launch and will continue during on-orbit assembly. Each launch will result in an alteration of the configuration, resource availability and operational constraints. To assure cost effective operation and mission effectiveness for each increment of the Space Station Freedom, an Increment Change Manager (ICM) will be assigned by the NASA Space Station Freedom Program Office. The ICM will oversee all activities from one Shuttle launch and its associated prelaunch activities to the next Shuttle launch including mission associated return cargo and post-landing activities. The ICM is responsible for the conduct of the mission during the increment including the pre/post mission operations. Reporting to the ICM is a Payload Accommodations Manager (PAM) and a Launch Site Support Manager (LSSM).

The PAM, appointed by Level II from the appropriate WP center, will be responsible for coordinating all User activities for a particular mission including activities of any User/payload groups. The LSSM, appointed from Kennedy Space Center, will be responsible for coordinating all launch site and landing site activities for a given increment.

A typical integration schedule is shown in **Figure 5-1**.

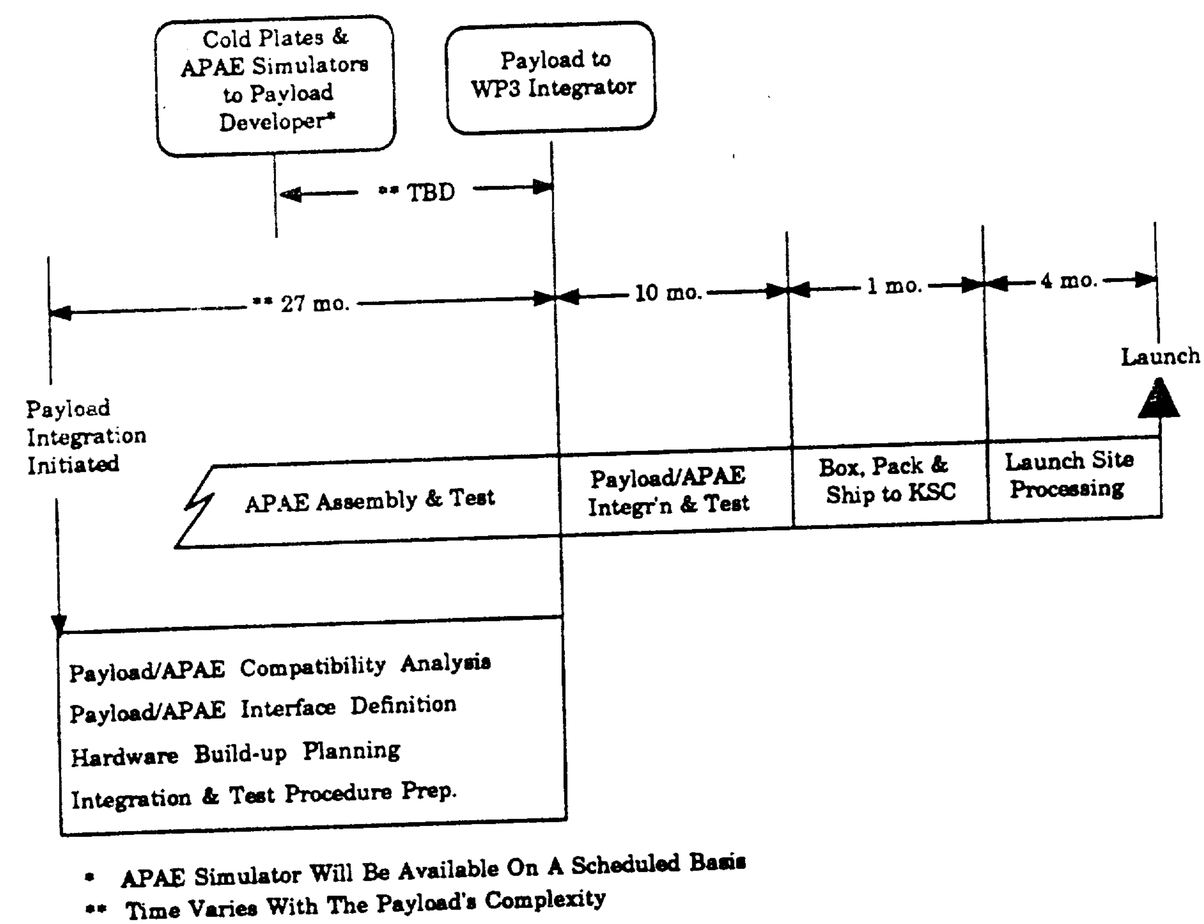


Figure 5-1. Typical payload integration schedule.

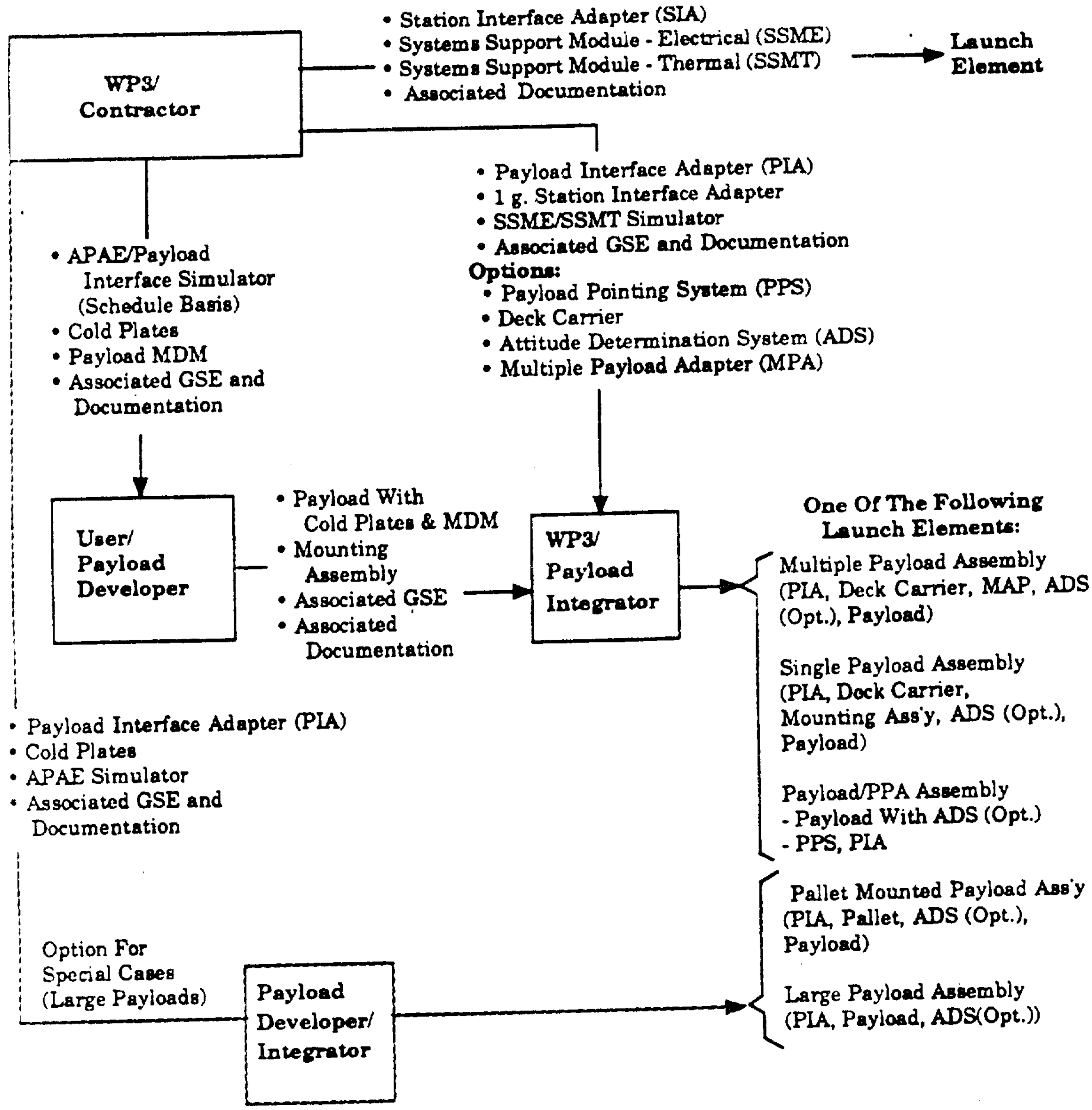


Figure 5-2. Typical APAE/payload hardware integration exchanges

Figure 5-2 identifies, for attached payloads, the typical exchanges of hardware between the different Payload Ground Processing Centers.

5.2 User Site Operations

The general payload ground processing flow begins at the User's facility. Once a particular payload has been chosen for flight, the following documents will be developed by WP3 and User/payload personnel: a Payload-to-APAE Compatibility Analysis; a Payload-to-APAE Interface Definition Document; a Hardware Build-up Plan; and Integration & Test Procedures.

The User will be required to develop test equipment to verify that the payload is operational. The test equipment will be used to monitor payload status during performance and environmental testing during prelaunch and post-landing processing at the PI Center.

Once the payload has ben verified, the SSFP will provide the payload developer at their facility an APAE simulator to simulate APAE payload interfaces. The payload developer will verify payload-to-simulated APAE structure, DMS, power, C&T, and thermal compatibility before the payload is sent to the PI Center for pre-flight integration with the APAE. The User provides the payload shipping container for shipment.

5.3 Goddard Spaceflight Center (GSFC) Payload Integration Centers

The GSFC PI Centers will be used to reduce the amount of processing that is required at the launch site. The GSFC PI Center will perform integration of payloads to the Space Station Freedom hardware, fit checks, compatibility tests, environmental tests, performance/functional tests, and trouble-shooting of problems encountered during testing.

A GSFC PI Center will integrate each payload with its APAE. The GSFC PI Center for attached payloads will initially be located at a GE Astro-Space Facility and later be moved to the GSFC. PI Centers will be certified by the Space Station Freedom Program. A payload provider may be the payload integrator for extremely large payloads and in other special cases. In these cases, the APAE and its associated GSE would be sent to the User facility for prelaunch integration.

The User will provide GSE and operators required to verify that the payload is functioning correctly. In addition to test equipment, Users will be responsible for providing any software required to operate/test the payload. Users must also provide any required operating procedures for verifying payload operability/ compatibility.

Once payload operability has been reverified, the payload will be integrated with the proper compliment of APAE. The integrated package will then undergo interface verification and compatibility and environmental tests.

The integrated launch element will then undergo an end-to-end test to verify that the SSFMB Control Center (SSCC) can adequately command and monitor the payload and APAE. This test will also verify the capability for transmission of data and communications between flight elements, the payload, applicable support equipment, the Payload Operations Integration Center (POIC), and the different NASA Engineering Support Centers (ESCs). At completion of the testing activities, the hardware will be configured for launch and will remain in this configuration for the rest of the launch processing flow.

A typical flow of integration is shown in **Figure 5-3**. Once this testing has been completed, the integrated launch element will be shipped to the launch site.

5.4 Launch Site Operations

Launch site testing will be performed to verify: the integrity of the launch element after transportation; Payload/APAE compatibility with the launch vehicle; and any APAE-to-Space Station Freedom interfaces that have not previously been tested.

The following guidelines are established for prelaunch processing:

- Payloads will be integrated with the APAE and will be fully assembled and tested prior to arrival at the launch site.
- APAE elements and payloads will be shipped to the launch site in a flight manifest configuration.
- Disassembly of the launch elements for checkout or interface testing will not be required.
- Prior to shipment to the launch site, pointing payloads will be integrated with the PPS or a PPS simulator, tested, aligned, and then separated into two launch elements.
- Reintegration at the launch site will not be required or performed.

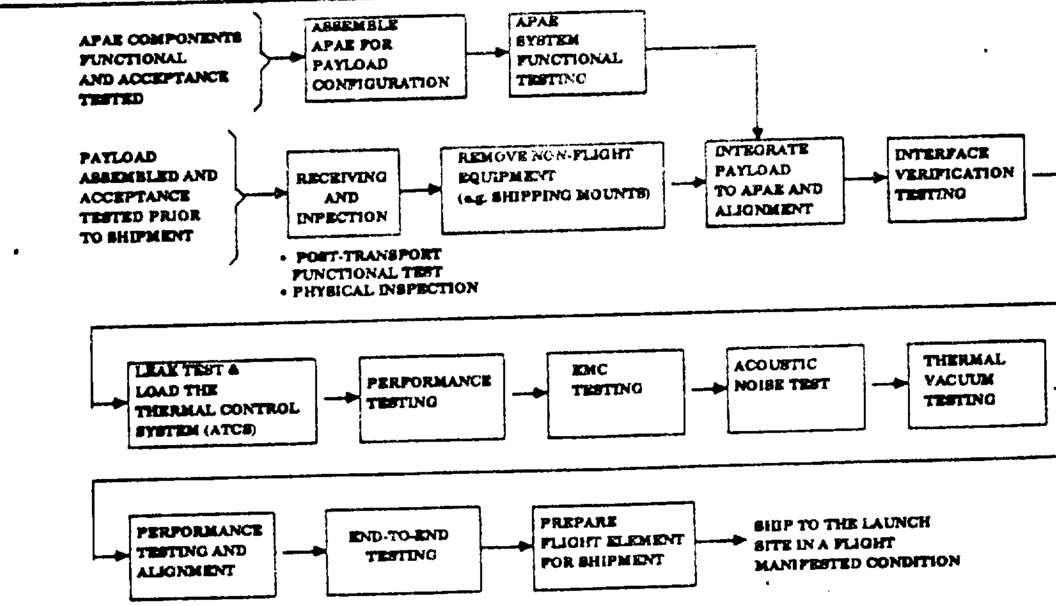


Figure 5-3. Typical flow of integration activities.

While at the launch site the Payload/APAE package will undergo Receiving and Inspection (R&I), Space Station Freedom Processing Facility (SSPF) On-Line Testing, and Launch Complex 39 Testing. User participation should be provided to effectively verify post-transport payload operability. Integrated User/APAE procedures will be used to verify payload and APAE operability and compatibility.

5.4.1 Launch Site Receiving and Inspection (R&I) Operations

A typical flow diagram for the activities that occur in R&I is shown in **Figure 5-4**. User personnel will participate with WP3 personnel in launch site R&I. Procedures utilized at the payload developer site will be used to the extent possible to verify payload operability.

5.4.2 Launch Element On-line Processing Operations

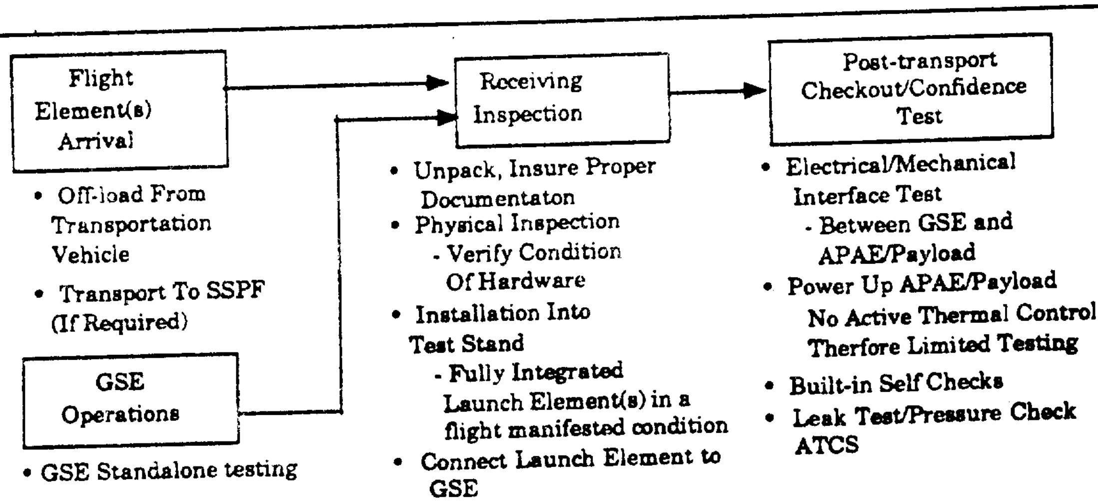


Figure 5-4. Typical receiving & inspection activities.

Once the launch element (payload/APAE assembly) has gone through R&I, it will enter the launch flow. A typical flow is shown in **Figure 5-5**. The User developed procedures will be used to the extent practical during launch site testing. Personnel from WP3 and the User site will accompany the payload throughout the cycle to disposition discrepancies that might occur during on-line tests.

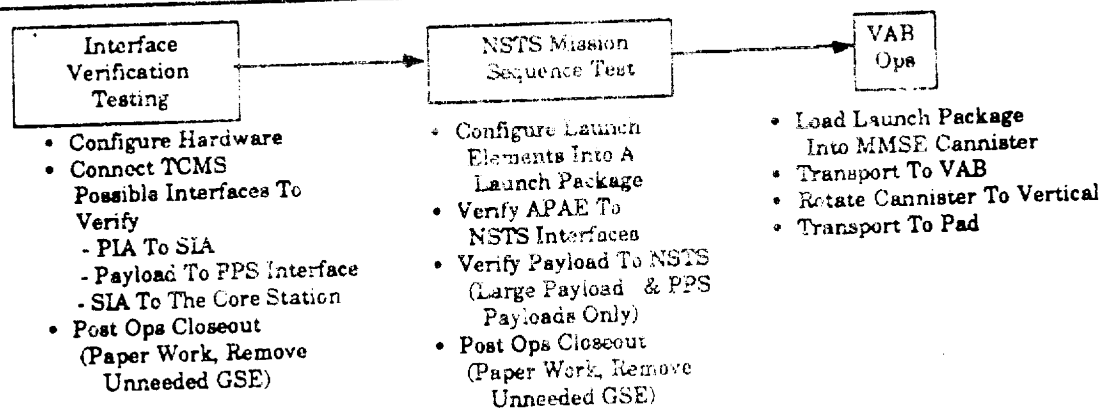


Figure 5-5. Typical flow for on-line testing activities.
(KSC/PGOC responsible, supported by WP3 contractor)

5.4.3 NSTS Testing

5.4.3.1 NSTS Safety

A maximum of three safety reviews will be required for Users in accordance with SSFP Document TBD. These reviews will combine the NSTS transportation to orbit phase, the on-orbit operational phase, and the return to earth by the NSTS phase. Participants at these reviews will include JSC, KSC, SSFPO, the Astronaut Office, and WP3. Payloads will be required to meet the standards set forth in NHB 1700.7A, KHB 1700.7A, and SSFP TBD (Space Station Freedom/NSTS Safety Requirements). Payloads will be required to verify compliance with safety requirements per SSP 30473, Space Station Customer/Experiment Verification Process Requirements.

5.4.3.2 Launch Vehicle Integrated Operation

The launch elements will be transferred from the SSPF to the pad and eventually into the Orbiter cargo bay. The launch vehicle integrated operations activities will include insertion of the launch package into the NSTS for interface verification, hazardous servicing and launch operations. A typical flow is shown in **Figure 5-6**.

5.5 Post-Mission/Landing Site Operations

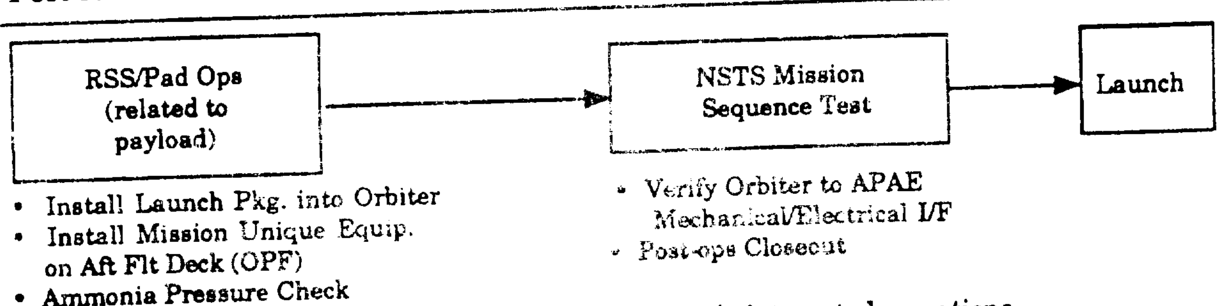


Figure 5-6. Typical flow for launch vehicle integrated operations.
(KSC/PGOC/SPC responsible with support from WP3 contractor and User)

When a payload is returned to the Earth, the general process is: the Orbiter will be safed; consumables and wastes processed from the vehicle; the payload/APAE de-integrated from the Orbiter; the payload/APAE prepared and shipped to GSFC PI center; the payload/APAE de-integrated; and then the payload prepared and shipped back to the User. Early access to payloads at the landing site may be accommodated on a negotiated basis.

6.0 PAYLOAD OPERATIONS

6.1 Overview

In general, the plans and procedures discussed in this section are to be developed by WP3 from inputs supplied by the Users. Accommodation assessments and general operations plans, procedures and equipment will be provided to the User by WP3 to insure that proprietary payload operations can be supported and associated data and products protected.

The WP3 Customer Operations Concept will describe the end-to-end operations associated with SSFMB attached payloads. This plan covers: payload ground operations; payload logistics; payload launch and on-orbit operations; facility interfaces; data handling; integration; de-integration; and return of payloads and data to the Users. The plan also includes end-to-end payload command and data paths, and storage and display capabilities. Safety considerations are included in the operations criteria.

The interface description includes remote Users (e.g., telescience), Regional Operations Centers (ROCs), Discipline Operations Centers (DOCs) both U.S. and Internationals, the POIC, the Integrated Test and Verification Facility (ITVF), ESCs, the Space Station Freedom Training Facility (SSTF), the NSTS Mission Control Center (MCC), WP3 contractor facilities, payload development facilities and the SSCC. Functional requirements for the POIC, DOCs, ROCs and the interfaces between them, the SSCC and Users will be defined and provided by the SSFP. The relationships among the POIC, SSCC, PI Centers, potential ROCs, and potential DOCs are TBD.

Consolidated Operations and Utilization Plan (COUP), Tactical Operations Plans (TOP) and the Integrated Execution Plan (IEP) will support long term payload activity planning throughout the Space Station Freedom Program lifetime. Executive level plans, (e.g., the Short Term Plan [STP] utilized on the SSFMB as part of the Operations Management System [OMS]), are used to support the real time payload activity planning.

Integrated Space Station Freedom payload operations plans and procedures will be developed. Users are responsible for developing and assuring the adequacy of detailed payload operations plans and procedures. Few, if any, restrictions other than those involving crew safety and SSPE integrity and multiple payload operations compatibility will be imposed on the User's operations. Resource envelopes will be assigned to Users to help insure SSPE integrity and payload operations compatibility. Interlocks will be utilized to prevent operations that could adversely affect crew or Space Station Freedom safety. The OMS, along with the APM, will ensure that payload operations are maintained within assigned resource envelopes.

6.2 Payload Operations Integration Center to SSFMB

The Space Station Freedom Program will provide a POIC. The POIC is responsible for coordinating payload operations for all payloads on the SSFMB. The POIC will be the focus of Investigator Working Groups (IWGs) for science management of mission increments and will provide the following User support functions:

- Centralized short and long range payload operations planning, scheduling and integration capability. (This capability includes near real-time management services, such as safety and utility systems interactions.)
- Centralized command, control, and display capability for Users, in addition to the telescience capability at DOCs. (The POIC provides interfaces to geographically dispersed Users at User Operations Facilities [UOFs], DOCs, ROCs and at User development sites via the SSIS.)
- Primary management center for payload operations
- A limited backup payload command and operations center
- Near real-time system status information for geographically dispersed Users
- Support integrated payload and Space Station Freedom/payload training activities
- Training for Users operating in the POIC or from remote operations centers/facilities
- User training support on a scheduled basis, without interfering with on-going operations.

The POIC provides an interface with the SSIS to perform the following functional capabilities:

- User friendly, standardized human interfaces for all services, including on-board computers for operations planning and management and on-board software updating
- Interfaces with the SSCC and various ESCs to support integrated real-time operations, payload/systems integration checks and integrated simulations
- Interfaces with the Operations Management Application (OMA) software.

The POIC also provides an interface with the SSIS to permit access to:

- Command, telemetry processing and display, and limit sensing services
- Command chaining and buffering services
- Mission planning system services to input requirements and requests and obtain mission plans and status, including the planning and scheduling of payload servicing and preventive maintenance
- Near real-time to stored telemetry data.
- Real-time voice and video communication and recording, including space-to-ground and ground-to-space
- Simple computations utilizing telemetry data in real and near real time
- Video conference capability with various NASA centers, DOCs, ROCs, UOFs and PI Centers
- Computer hardware/software capabilities for accommodating User defined and implemented rules with access to Space Station Freedom and payload telemetry data and with provision for issuing payload advisory messages and commands.

6.3 Onboard Payload Operational Services

6.3.1 Onboard Resource Services

The SSFP will provide a set of services allowing the execution of the on-orbit segment of the Payload Operations Plan. These services will provide a means for onboard storage and display of video images for use in payload operations support, payload system diagnostics and payload servicing operations. An end-to-end checkout of User space systems will be possible on-orbit. The crew will be capable of accomplishing scheduled and unscheduled servicing of payloads during assembly and operations phases.

The SSFMB will provide the following types of on-orbit capabilities: data storage, data processing, audio, video, and hard copy presentation of single frame imagery (including video) generated by attached payloads with compatible communication systems, and transmission services both uplink and downlink.

The SSFMB provides the following data capabilities:

- Transmit at least 275 Mb/s of User data to the ground and with a daily volume capacity of at least 1 (TBR) Terabyte (Tb)
- Handle data rates up to 100 (TBR) Mbps and analog video at each APAE attached payload location
- On-line, rapid access mass storage capability (TBD)
- Buffer storage capability and removable media capability for the Users with a total onboard storage capability of 1 (TBR) Tb to cover Tracking and Data Relay Satellite System (TDRSS) zones of exclusion and short term C&T outages
- Handle high rate payload data rates for data transfer, buffer storage, and C&T for transmission to the ground, as appropriate
- Electronic reallocation capability to interconnect, as required, input/output signals for payload communications.

Access to the data services is provided through standard network interface nodes and onboard work stations. The operating system and network access protocols are designed, where feasible, to provide performance levels which make the data system operation transparent to the User for both the uplink and downlink capability, under normal operations.

6.3.2 Onboard Payload Management Services

The Attached Payload Manager (APM) is a software package used onboard the SSFMB to manage the operations of attached payloads and the associated APAE including command generation and sensor monitoring for the PPS and the ADS. The APM provides single point communication for telemetry collection and data distribution to and from payloads. Automated analysis of telemetry and sensor data is available for fault detection/isolation/correction within the APAE and the payload. The payload will be placed in a SAFE/HOLD mode by the APM if a safety hazard is detected. The User must prepare corrective actions for other potential fault situations.

The User interfaces with the APM software through real time commands on the STP. Interfaces will use a common language developed for the Space Station Freedom. The User will participate in the development of the User Interface Language (UIL) and will provide all requirements applicable to his/her payload (e.g., time tag information, data transmission requirements, power, precision pointing requirements, gimbal re- quirements, viewing requirements, and thermal conditioning). The STP will schedule available resources.

Once the payload is in operation, the APM will monitor payload resource usage. Any anomalous conditions (e.g., over usage of any one resource or non-existent resource) will be detected and recovered through the APM. In these cases, the APM will issue a warning that the SSFMB does not have the resources to support the particular mode(s). It will be the responsibility of the Operations Management Application to resolve any resource conflict (e.g., bouncing based on priorities, rework the STP, or flag discrepancies to ground operations).

The transaction management function of the OMS focuses on managing the effects of commands, rather than the commands themselves. This is accomplished by an appropriate combination of interlocks (hardware and/or software) located logically and/or physically within the target system and reactive control. The service is transparent to the User, and will manage to limits imposed by the current operations schedule. Transaction management accommodates telescience by supporting real-time, interactive control and rapid replanning to accommodate changing needs and targets of opportunity.

6.4 On-orbit Ground Services

The SSIS ground data network links facilities such as the POIC, SSCC, ESC, DOCs, and ROCs. Along with the Program Support Communications Network (PSCN) and the NASCOM, the SSIS provides the near real-time capability to route payload data to remote User facilities and to route commands from these facilities to payloads on the SSFMB. The SSIS provides all of the design-to requirements for the ground data network interfaces for space systems operations and space systems ground support facilities.

Downlink data is routed to the User and to other facilities through a virtual network or a network with similar capabilities. A capability to route crew voice and dynamic video imagery to the POIC, and SSCC (video only) will be provided. A capability will be provided to route audio and video imagery to DOCs, ROCs, and UOFs.

The SSIS will have the capability to synchronize audio and video data. The SSIS will also provide teleconference capability with the POIC, the SSCC, ESC payload operators, and the NASA centers and associated training facilities.

The SSIS will support near transparent communications of User commands and data uplinks from the Users' ground facility to User equipment on-orbit subject to resource envelope management and safety considerations.

The following capabilities and functionality will be provided:

- Support for monitoring and control of payload systems during buildup and operational phases of the mission for time periods specified by the Users
- Minimal disruptions in User
- Transparent to the User
- Storage of User data
- Maintenance of Space Station Freedom operations logs and histories which document all major activities, including those activated by ground Users, flight crew, and automated systems
- Ancillary data to the Users to support data processing requirements
- Standard capabilities to compute pointing references for those payloads that view phenomena external to the SSFMB
- Range of high-precision standard frequency and time references for onboard Users
- Security measures to cover all User applications in accordance with international law
- Private encryption support mechanisms

6.5 Command and Control Support

Space Station Freedom command sequence services with the following attributes are to be provided:

- Simultaneous command sequence execution capability
- Capability for individual Users to submit, propose modifications to, and schedule their command sequences and payload software utilizing the transaction management function
- Security provisions to prevent one User from impacting another User
- At least one level of nesting command sequences
- Ability to chain command sequences
- Ability to initiate commands based on Universal Time Coordinated (UTC) or delta time in a command sequence
- Ability to initiate or inhibit conditional commands based on sensor values and contingency modes (within resource and safety envelopes)
- Capability to dynamically and automatically alter downlink bandwidth allocations based on priorities of data sources.

6.6 Payload Servicing

The baseline SSFP will provide limited servicing and storage capability in support of attached payloads. Robotic support will be provided by the MSC with a SPDM or the FTS. EVA backup for all robotic functions will be accommodated.

6.7 User Logistics

6.7.1 General

The SSFP is capable of returning all User equipment and material to Earth in a safe condition. User-provided canisters may be required. The Integrated Logistic Support System (ILSS) includes an information system for coordination planning, reviews and analysis. The ILSS also supports: fluid management; maintenance planning; supply planning; training; and technical data packaging, handling, storage, and transport.

6.7.2 User Payload Logistics

Support for payloads during ascent/descent are TBD. Capabilities for accommodating expendable launch vehicle (ELV) payload logistics transportation are TBD.

6.8 Training

6.8.1 General

The Space Station Freedom Training Working Group will review User training facilities, simulation equipment and training processes to ensure that training requirements will be met. A User Training Plan and materials will be developed for training User ground operators and Payload and Station Scientists. Requirements for optional User-unique training services will also be identified.

6.8.1.1 General Training Operations Concept

The training operations concept includes the flight crew, the user ground operations team, logistics including maintenance and repair, and launch contractor operations. The training program has been divided into four increasingly complex levels which are applicable to specific roles and responsibilities.

6.8.1.1.1 Familiarization and Basic Knowledge Levels

Training will begin at the familiarization level where trainees will use programmed instruction (either Computer Aided Instruction [CAI] or video tapes) to attain a general understanding of the overall program and the tasks applicable to specific positions.

Basic knowledge level of training will provide the trainee with sufficient information and experience to generally perform the activity. Basic knowledge training will consist primarily of programmed instruction in considerably more detail than provided for familiarization.

6.8.1.1.2 Proficiency Levels

Nominal level proficiency requires that an individual be fully trained to perform all normal operations. To accomplish nominal level proficiency, trainees will, in addition to familiarization and basic level training, receive classroom instruction and hands-on experience using simulators, high fidelity mockups or non-flight hardware.

Full proficiency requires the individual to be fully trained to perform all normal operations, maintenance operations, and emergency procedures. After reviewing familiarization and basic knowledge instructional material, trainees will receive training not only in all normal operations, but also full training in malfunction operations and emergency procedures. Only flight crew and ground control team leaders will be trained to the full proficiency level.

6.8.1.2 WP3 Training Plan

A WP3 Training Plan will be provided. This training plan will provide an overall description of the training courses and schedules consistent. The training plan will include individual course syllabi, materials, manuals, requirements for simulation, and training requirements for non-flight hardware operations.

6.8.1.3 Certification

Certification of proficiency of performance resulting from training will be required. Operational positions requiring high levels of performance require certification of operators in all important and critical tasks. Certification shall be based on an overall review of hands-on training scores and classroom test results. Anyone who manufactures, assembles, tests, or operates flight hardware from a console shall be trained and certified for that specific activity.

6.8.2 Crew Payload Training

The Space Station Freedom Program will provide the User with training guidelines. Users will be responsible for the development of the training materials and simulation requirements necessary to train the crew on the operation of their payload. Also to be provided by the User are: mockups and simulators; software required to support payload training operations involving safety critical processes; and training materials, procedures, and equipment required because of payload activities having a large impact on other User operations or requiring complex EVA or IVA crew/manipulator activities. An onboard SSFP User training capability will be provided for job performance assistance, refresher training and crew skill proficiency maintenance.

6.8.3 User Ground Support Team Training

Software and video media will be provided by the SSFP for remote training of User ground personnel on Space Station Freedom payload support systems capabilities and normal and contingency operations. User ground teams will be required to participate in integrated simulations to demonstrate how their payload impacts, and is impacted by, the operations environment. User personnel will interact with their payloads via workstations. Workstations must be compatible with SSIS and TMIS. Workstations may be provided by the SSFP or the User.

Appendices

Appendix A: Reference Documents

Appenidx B: NSTS/Orbiter Payload Accommodations

Appendix C: Worst Case Payload Environments

Appendix D: Definitions

Appendix E: Acronym List

Appendix A: Reference Documents

JSC 30426, Contamination Control Requirements for Space Station.

JSC 30219, Space Station Coordinate System Document

KHB 1700.7A, Space Transportation System Payload Ground Safety Handbook.

NASA-STD-3000, Vol IV, Space Station Man-Systems Integration Standards

NHB 1700.7A, Safety Policy and Requirements for Payloads Using the Space Transportation System.

NSTS-07700, Volume XIV, Space Shuttle System Payload Accommodations.

NSTS-21000-IDD-SML, Shuttle/Payload Interface Definition Document for Small Payload Accommodations.

NSTS-21000-IDD-STD, Shuttle/Payload Interface Definition Document for Standard Accommodations.

Space Station Program, Program Requirements Document, Appendix A, Program Description.

Space Station Freedom Assembly Sequence, Trial Payload Manifest, Release 1.0, December 1988.

SSP 30000, Rev.B, "Space Station Program Definition And Requirements, Section 5: User Integration & Operations Requirements.

SSP 30205 -External Thermal Environmental Data Base Geometric Math Model

SSP 30206 -External Thermal Environmental Data Base Thermal Math Model

SSP 30237 Space Station EMI/EMC Requirements

SSP 30240, Space Station Grounding Standard

SSP 30425-Natural Environmental Definition for Design

SSP 30249-Electromagnetic radiation, ionizing radiation & plasma

SSP 30482 Space Station Electrical Power

Appendix B: NSTS/Orbiter Payload Accommodations

B.1 Standard Payload Accommodations

The Orbiter systems are designed to support a variety of payloads and payload functions. The payload and mission stations on the flight deck provide space for payload-provided command and control equipment for any payload conditioning required by the User during space transportation. The following supporting subsystems are provided for payloads.

- Payload attachments
- Remote manipulator handling system
- Electrical power, fluids, and gas utilities
- Environmental control
- Communications, data handling, and cockpit displays

All payloads have one or a combination of interfaces with the Orbiter vehicle. The vehicle is designed to provide adequate standard interfaces that can be used by, or adapted to, most potential payloads. Basic types of interface are summarized in **Figure B-1**. Additional support systems and flight kits are also available to accommodate payloads.

Accommodations are available for up to four standard payloads per flight and are allocated according to individual payload requirements and load factors. Detailed specifications and interface characteristics of these services are defined in Shuttle/Payload Interface Definition Document for Standard Accommodations, NSTS 21000-IDD-STD, current issue.

B.1.1 Physical Accommodations

The Orbiter has structural support attachment points for customer provided trunnions along the length of the payload bay, as indicated in **Figure B-2**. Payloads can be supported by attach fittings at numerous points along both sides of the payload bay and along the bottom at the Orbiter keel center line. For deployable payloads, active fittings are used which provide load reaction and strain isolation between the Orbiter and payload. The fittings are designed to be adjusted to specific payload weight, volume, and center of gravity distribution in the bay. The fittings to attach payloads to the bridge fittings are standardized to minimize payload change out operations. To further minimize payload operations involving the Orbiter, standard payload handling interfaces have been provided. The most common arrangements are three point and five-point designs, as illustrated in **Figure B-3**.

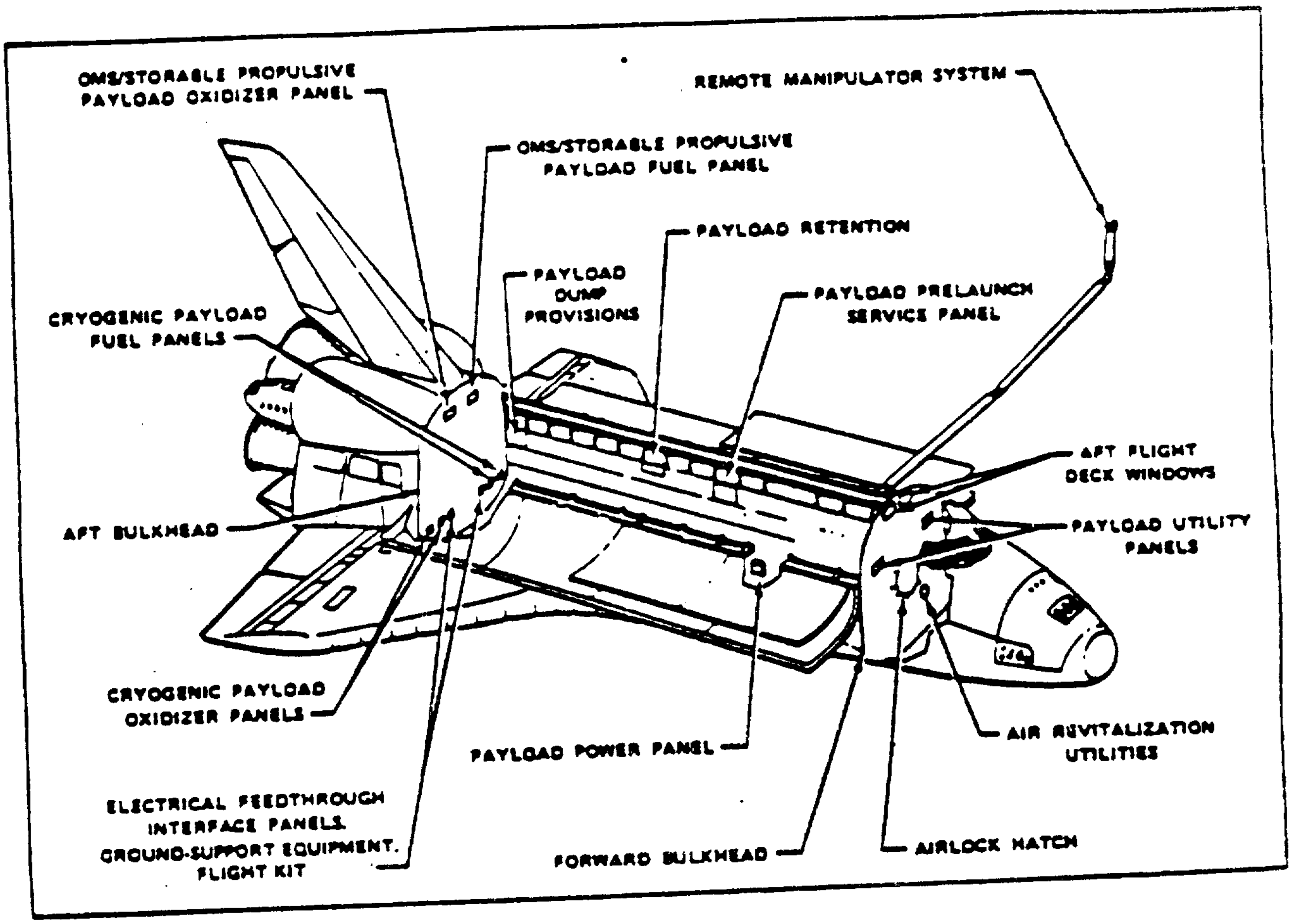


Figure B-1. Principal Orbiter interfaces with payloads.

ORIGINAL PAGE IS
OF POOR QUALITY

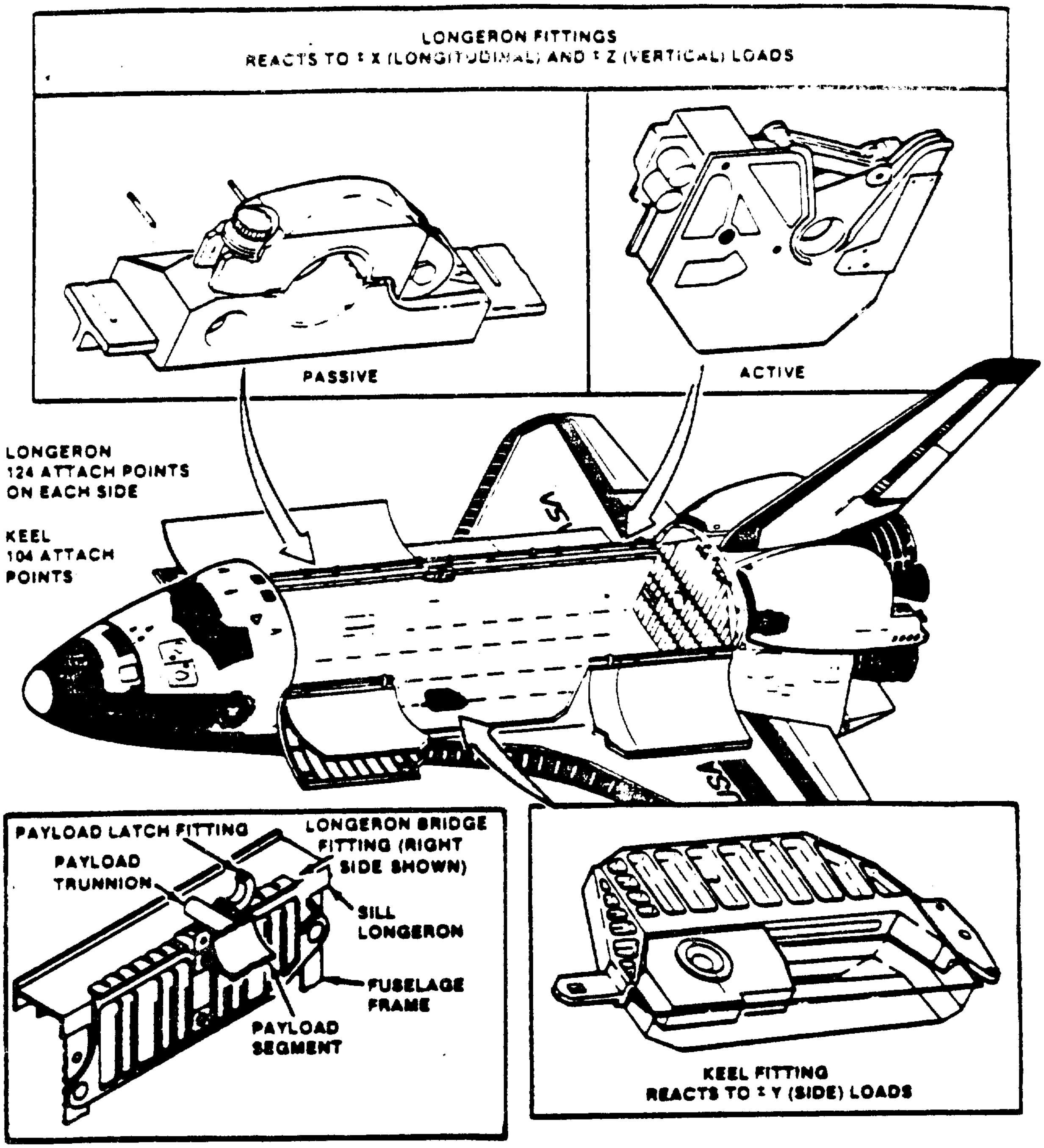


Figure B-2. Attach fittings for payloads.

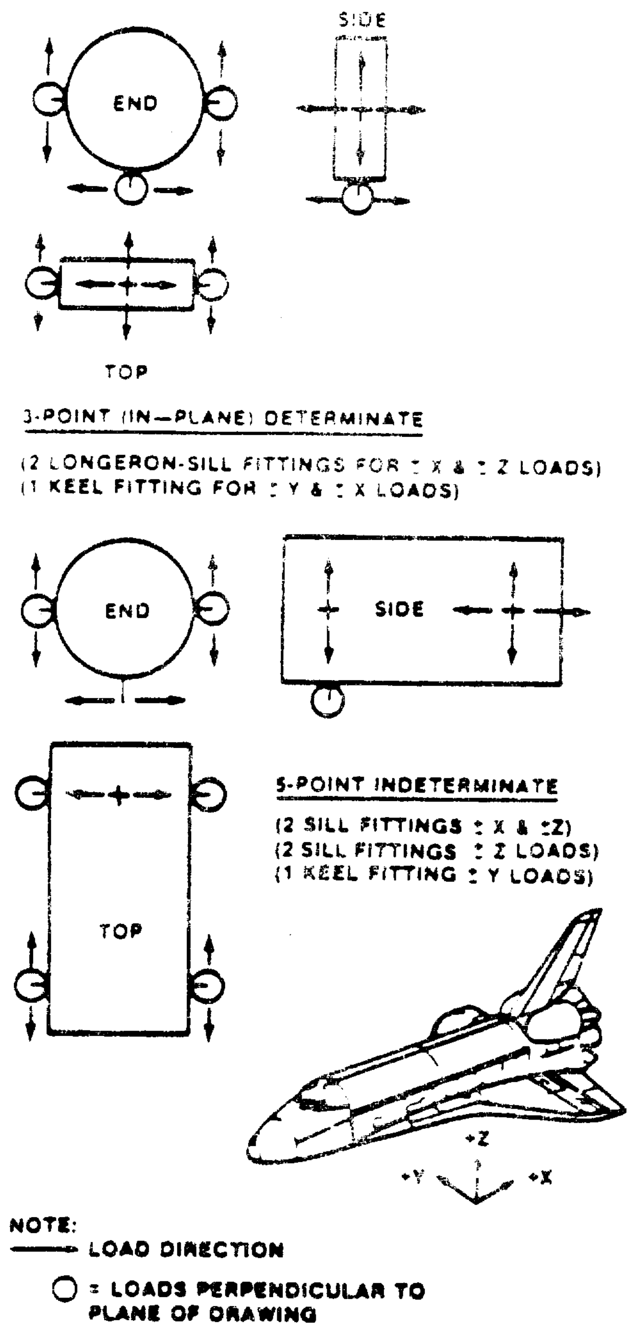


Figure B-3. Three- and five-point loads support.

B.1.2 Envelope Available to Payload

Payload Accommodations are provided in two general areas of the Orbiter: the cargo bay and the aft flight deck in the cabin. The dimensions and envelope of the bay are illustrated in **Figure B-4** along with the structural and payload coordinate systems. The Orbiter stations are included for reference.

The cargo bay is covered with doors that open to expose the entire length and full width of the cargo bay. The usable envelope is limited by items of supporting subsystems in the cargo bay that are charged to the payload volume.

The maximum payload envelope in the Orbiter cargo bay is cylindrical in shape measuring 15 feet (4.5 meters) in diameter by 60 feet (18.3 meters) in length. This is the maximum allowable payload dynamic envelope, including payload deflections. This volume is, however, almost never fully available due to Shuttle Program reserves. A nominal three inch (7.6 cm) clearance has been provided between this payload envelope and the Orbiter structure in order to prevent deflection interference between the Orbiter and the payload envelope. **Figure B-5 a** and **b** illustrate the key dimensional parameters.

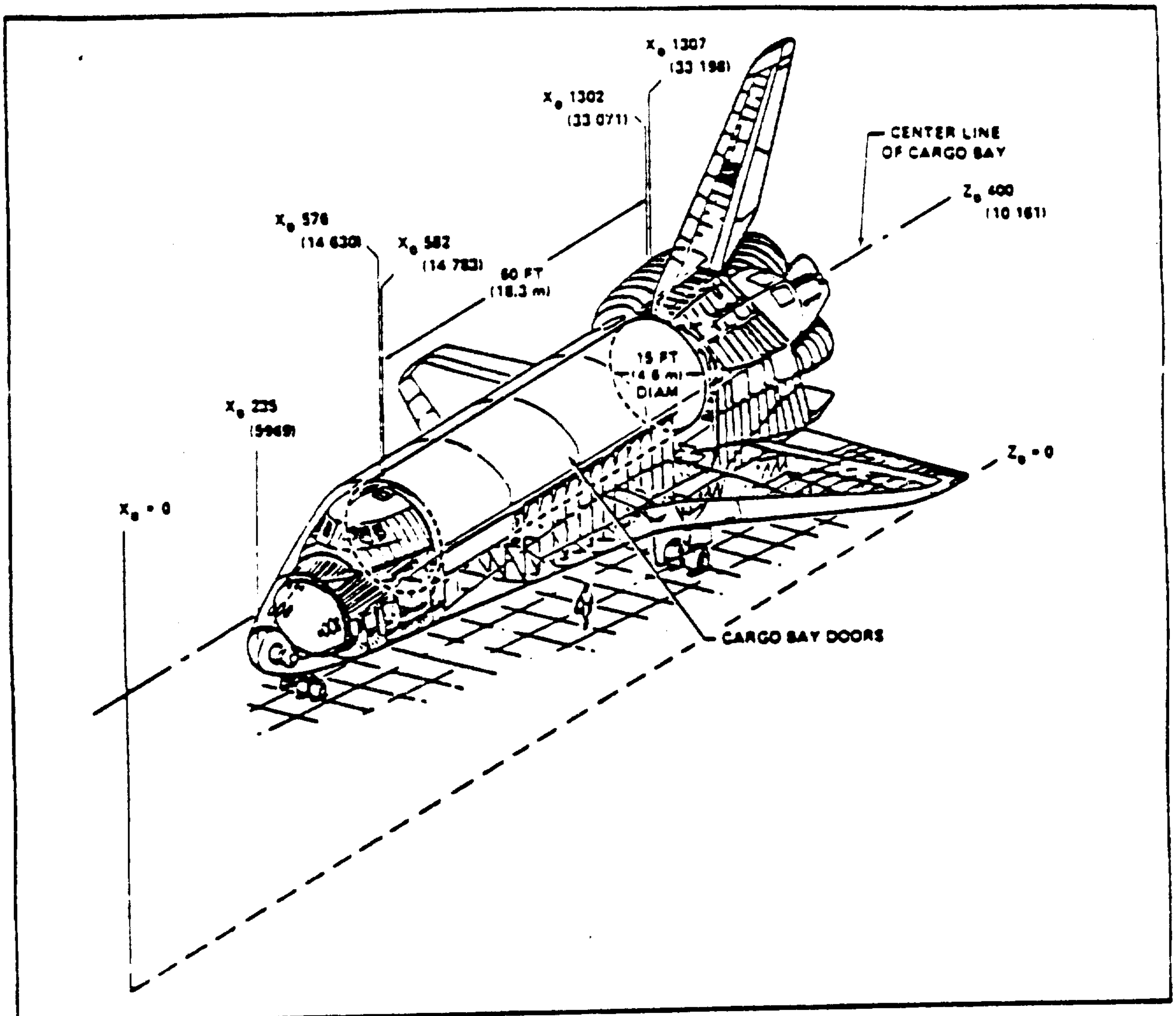
B.1.3 Cargo Bay Liner and Shrouds

The cargo bay has been designed to minimize contamination of critical surfaces. Use of nonmetallic materials has been limited to those with low outgassing characteristics. Those areas that cannot be readily cleaned can be isolated from sensitive payload surfaces by the installation of a cargo bay liner, which does not intrude into the payload envelope.

Payloads that require additional protection from contamination can be provided with a shroud. Such a shroud is considered part of the payload and is contained within the payload envelope of the cargo bay.

B.1.4 Weight and Center of Gravity

The location of the cargo center of gravity is critical during aerodynamic flight. Weight and center of gravity calculations must take into account all items of supporting subsystems charged to the payload Cargo center of gravity envelopes for each axis of the Orbiter as shown in **Figures B-6 a, b and c.**



Orbiter coordinate system and cargo bay envelope. The dynamic clearance allowed between the vehicle and the payload at each end is also illustrated.

Figure B-4. Orbiter coordinate system and cargo bay envelope.

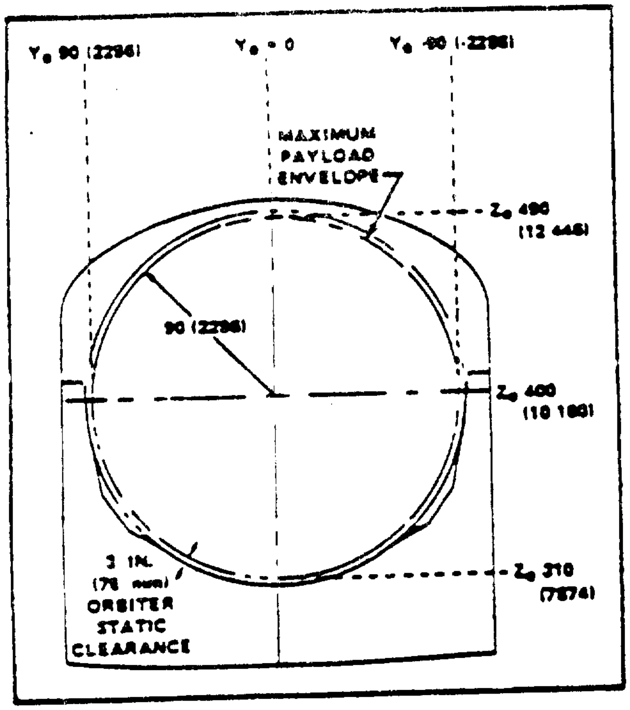


Figure B-5a. View of payload looking aft.

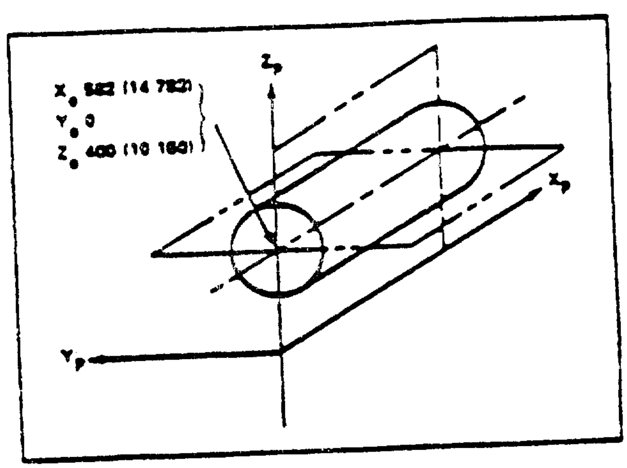


Figure B-5b. Payload coordinates showing relationship to each Orbiter axis.

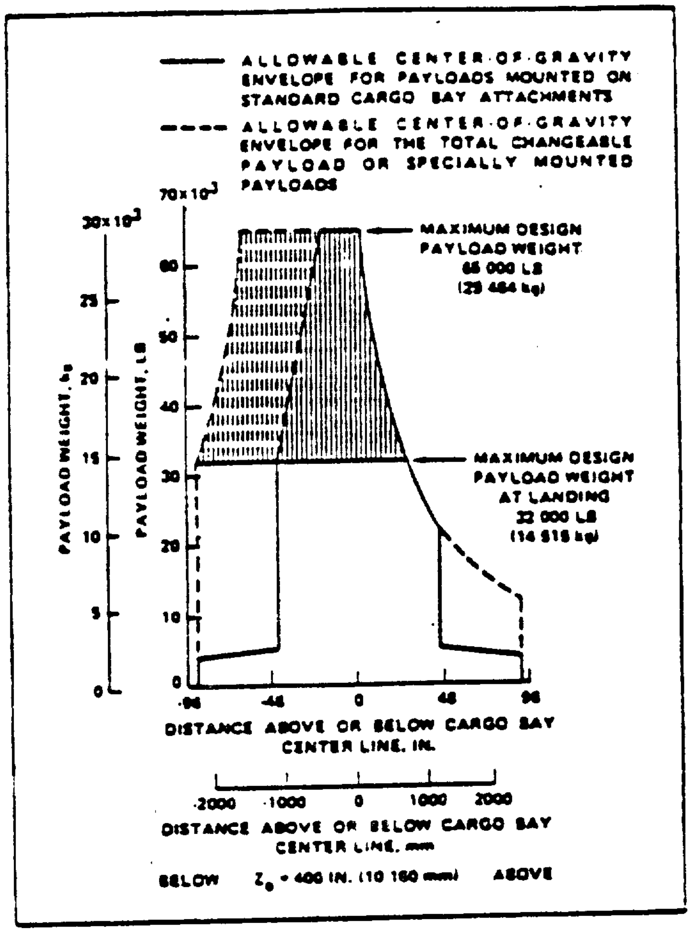


Figure B-6a. Center-of-gravity limits for cargo along the Orbiter Z-axis.

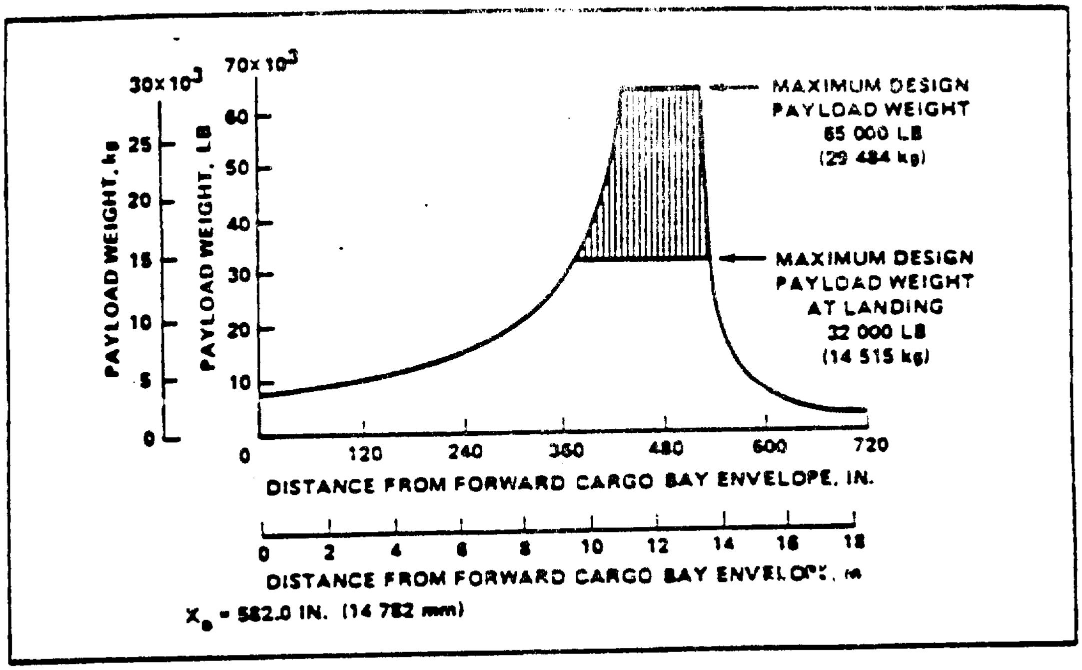


Figure B-6b. Payload center-of-gravity limits along the Orbiter X-axis.

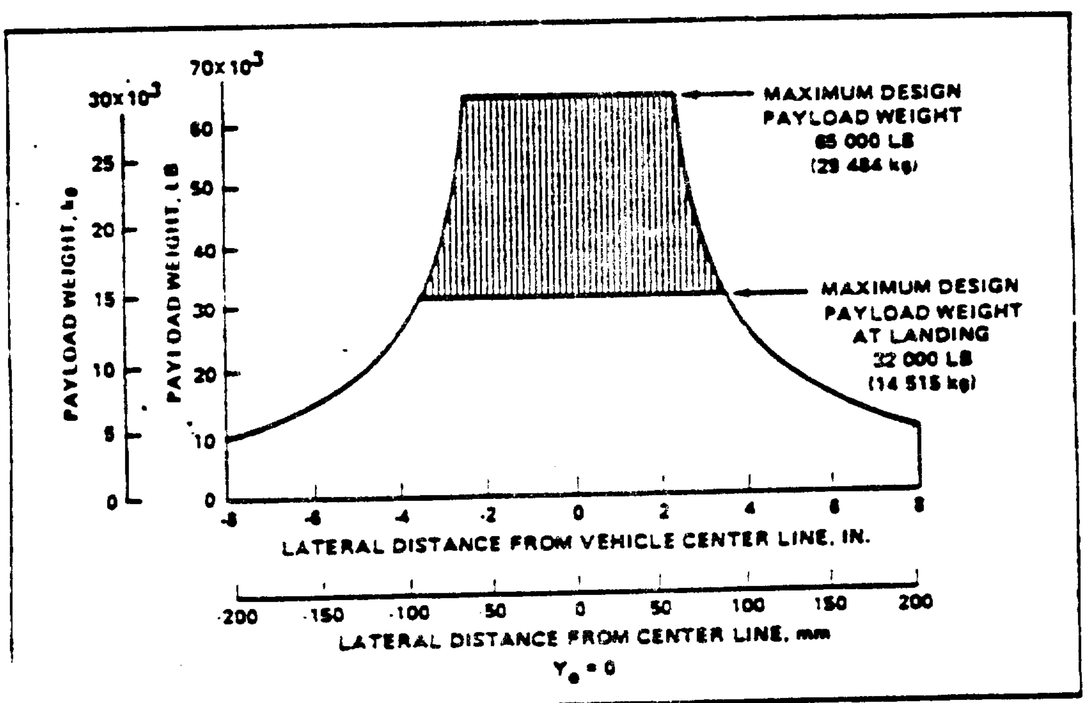


Figure B-6c. Allowable center-of-gravity envelope along the Orbiter X-axis.

During normal landings and abort operations the center of gravity must fall within these envelopes. Out-of-envelope conditions are permissible during launch and space flight. However, the conditions must be correctable before reentry or in the event of an abort on launch. Each proposed out-of-envelope condition will be evaluated individually. For additional information, refer to Appendix 4 of NSTS 07700 Vol, XIV, Rev. J.

B.1.5 Avionics Accommodations

B.1.5.1 General

Avionics services such as power, command, and data are furnished to payloads using a standard mixed cargo harness (SMCH). The SMCH cables are routed by payload wire trays on the port and starboard sides of the Orbiter payload bay. The SMCH provides power interfaces on the starboard side of the payload, signal and control interfaces on the port side, and Orbiter computer data bus interfaces on both port and starboard sides of the payload. The SMCH is routed to a standard interface panel (SIP) adjacent to the payload (**Figure B-7**), thus minimizing the length of the payload-provided cable to the SIP from the payload.

The Orbiter communications and tracking subsystem provides links between the Orbiter and the payload. The use of this subsystem would normally be restricted to command and telemetry related to the health of the payload in the cargo bay and/or to the conditioning of the payload for transfer from orbiter to SSFMB.

B.1.5.2 Electrical Power

Orbiter electrical power is distributed to payloads at the SIP. Nominal voltage of 28 Vdc is provided during ground operations, ascent, orbital operations, and descent. For prelaunch operations, a total of 250 watts is available with up to 1750 watts available for payload verification operations in the Orbiter. For ascent or descent, a total power of up to 250 watts is available.

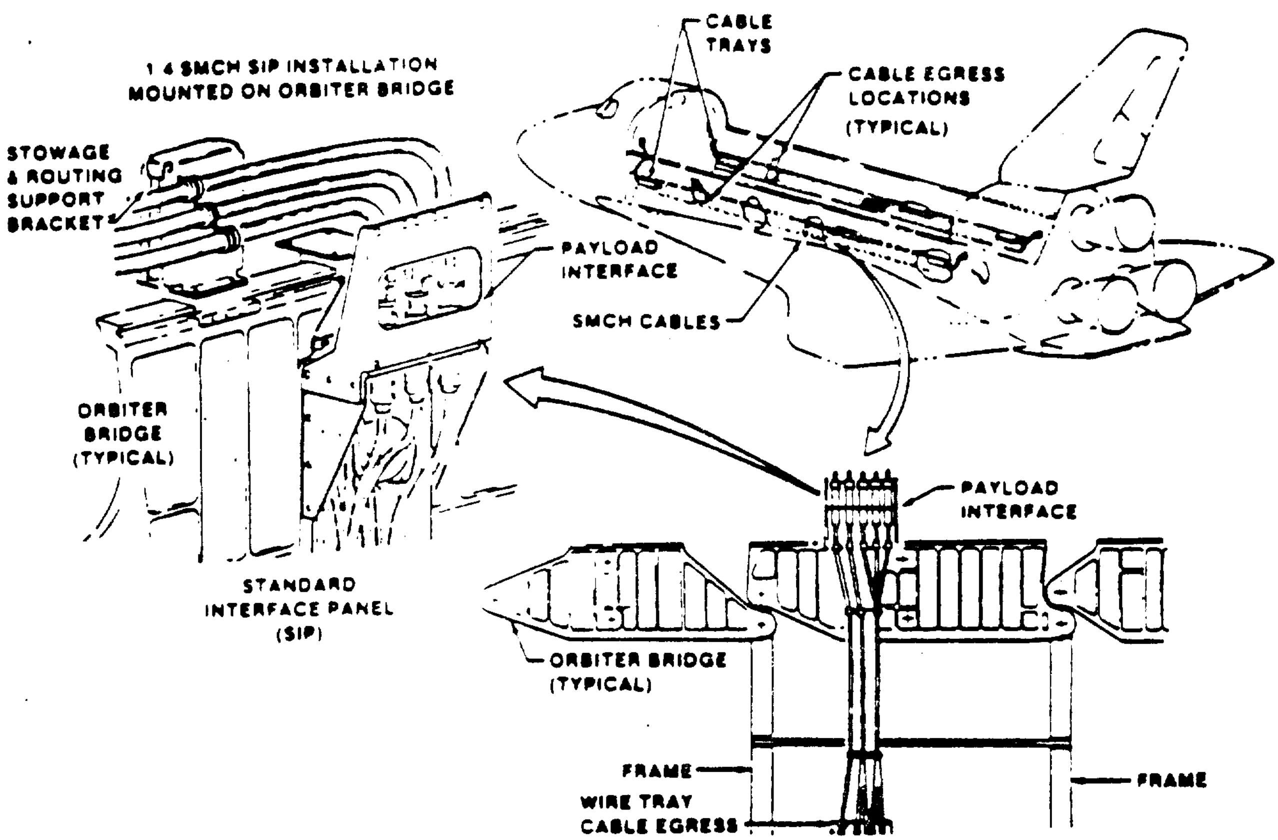


Figure B-7. Standard interface panel configuration.

ORIGINAL PAGE IS OF POOR QUALITY

B.1.6 Thermal Accommodations

The STS can provide nominal thermal environments which meet the requirements for most payloads. During prelaunch and post-landing, the payload bay purge provides limited thermal conditioning shown in **Table B-1**. Air-conditioning and purge requirements are defined by analysis for each launch.

During the ascent trajectory, the Orbiter construction and insulation limit the Orbiter induced heat loads on the payload. During ascent and descent, when the cargo bay doors are closed and the radiators are ineffective, cooling is provided by the water boilers. The heat rejection capability when the cargo bay doors are closed is 1.52 kW average with peaks limited to 2 minutes. At 600 seconds after launch, the Orbiter is in the on-orbit phase and the cargo bay doors can be opened.

On-orbit with the payload bay doors open, a wide range of thermal environments is possible and is limited by the attitude hold capability of the Orbiter and payloads in the payload bay. Actual thermal environments are dependent upon a number of factors which include the thermal interactions between the Orbiter and the payloads in the payload bay.

A detailed analysis of each payload may be necessary before thermal design and integration. For preliminary calculations, the optical properties of the cargo bay liner, Orbiter radiators, and insulated forward and aft bulkhead surfaces are as follows, where a is absorption and e is emissivity.

- Cargo bay liner — $a/e \leq 0.4$
- Radiator surface — $a/e = 0.10/0.76$
- Forward and aft bulkheads — $a/e \leq 0.4$

Orientation during docking to the SSFMB may require special consideration of solar beta angle. Cargo temperatures for a typical flight, with emphasis on the entry phase, are shown in **Figure B-8**. For mixed cargo payloads, the payload design must be compatible with standard purge and attitude requirements as defined in NSTS 21000-IDD-STD.

TABLE B-1

Ground purge capability

Parameter	Location			
	Before launch pad		Postlanding and runway to OPF[a]	Transfer (VAB[b] to OPF, VAB to pad, OPF to VAB)
	Noncryogenic payload	Cryogenic payload		
Gas type	Air/GN_2[c]	GN_2	Air	Air
Temperature range, ±2° F (±1.1 K) (at T–0 umbilical inlet)	45 to 100 (280 to 311)	45 to 100 (280 to 311)	45 to 100 (280 to 311)	65 to 85 (291 to 303)
Flow rate, lb/min (kg/min)				
Spigots closed	110 (50)	364 (165)	115 (52)	115 (52)
Spigots open				
Spigots	150 (68)	150 (68)	136 (62)	136 (62)
Manifold	110 (50)	215 (97)	101 (46)	101 (46)
Total (spigots open)	260 (118)	364 (165)	220 (100)	220 (100)
Supply pressure, psig (N/m^2)	2.5 (17 236)	10 (68 940)	2.0 (13 788)	2.0 (13 788)

[a]OPF = Orbiter Processing Facility.

[b]VAB = Vehicle Assembly Building.

[c]Initiate gaseous nitrogen (GN_2) purge 80 min before cryogenic tanking of the Shuttle system to inert cargo bay

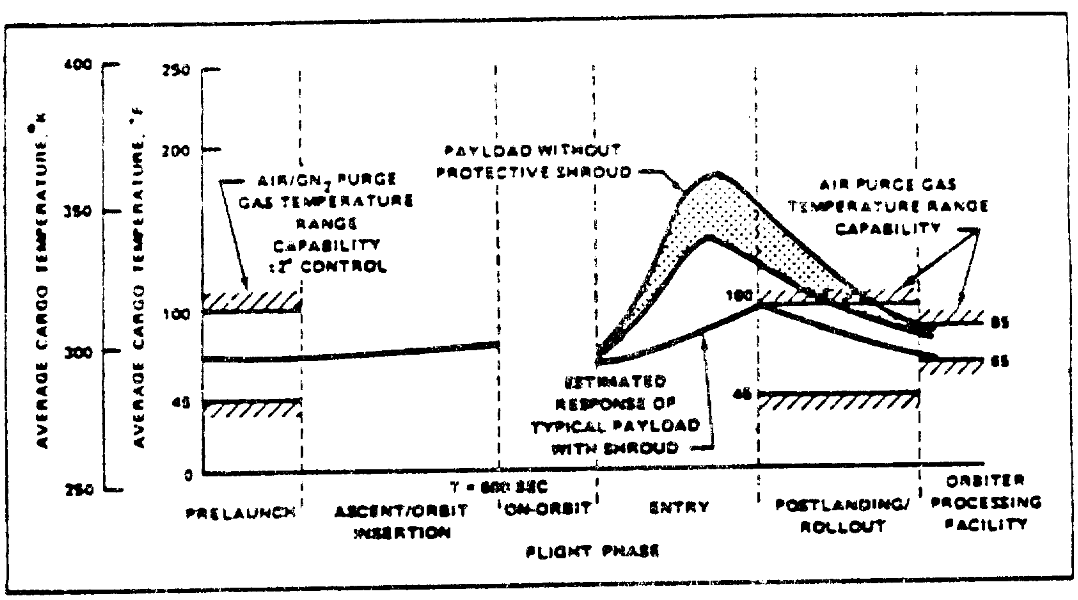


Figure B-8. Cargo bay thermal environment during the phases of a typical flight.

B.1.7 GSE Umbilical

The GSE umbilical, also known as the T-0 umbilical, is separated from the Orbiter at liftoff. T-0 umbilical wiring is provided to enable payload monitoring, commanding, and trickle charging of batteries prior to liftoff.

B.2 Small Payload Accommodations:

Small payload accommodations are available to support payloads which do not require the full range of standard accommodations. Detailed specifications of the services and interface characteristics are defined in Shuttle/Payload Interface Definition Document for Small Payload Accommodations, NSTS 21000-IDD-SML, current issue.

B.2.1 Physical Accommodations

Payloads using small payload accommodations can be mounted in either a side-mounted or an across-the-bay configuration. In the side-mounted configuration, the payload is mounted on a side wall payload carrier. This accommodation is available only on the starboard side of the payload bay. The side wall payload carrier is similar to the typical Orbiter bridge shown in **Figure B-2**

In the across-the-bay configuration, the payload is mounted on a customer provided structure using the attachment provisions described in section B.1.1. For more detailed information, refer to Appendix 4 of NSTS 07700, Volume XIV, Revision J, 1/27/88.

B.2.2 Electrical Power

A maximum of 1400 watts of nominal 28 Vdc electrical power is available at the payload interface for prelaunch checkout and orbital operations. Small payloads may be constrained to 300 watts during another payload high power demand period.

B.2.3 Thermal Accommodations

For a small payload, the accommodation is limited to the expected payload bay thermal environments. Small payloads should be designed with a self-contained thermal control system and for thermal attitude capability equivalent to the Orbiter as given in NSTS 21000-IDD-SML. The customer is responsible for performing the integrated thermal analysis to assure that the payload thermal attitude capability is equivalent to that of the Orbiter.

B.3 Remote Manipulator System (RMS)

The RMS is the mechanical arm component of the payload deployment and retrieval system (PDRS) which is devoted to payload deployment, retrieval, special handling operations, and other Orbiter servicing. It is 50 feet 3 inches in length and is mounted along the port longeron of the payload bay, outside of a 15-foot diameter envelope reserved for cargo.

One manipulator arm is standard equipment on the Orbiter and can be mounted on either the left or the right longeron. A second arm can be installed and controlled separately for payloads that require handling with two manipulators. Manipulators cannot be operated simultaneously. However, the capability exists to hold or lock one arm while operating the other. Each arm is associated with remotely controlled television cameras and lights to provide side viewing and depth perception. Lights on truss and side bulkheads provide sufficient illumination levels for any task that must be performed in the cargo bay. Manipulator operation and arm dimensions are indicated in **Figure B-9.**

B.4 Optional Services and Accommodations:

In addition to the standard and small payload accommodations, the STS can provide other services to support payload operations. These services are generally not required by the majority of STS payloads and are unavailable for small payloads. Some are restricted by Orbiter design and can be provided to only a limited number of payloads on each flight.

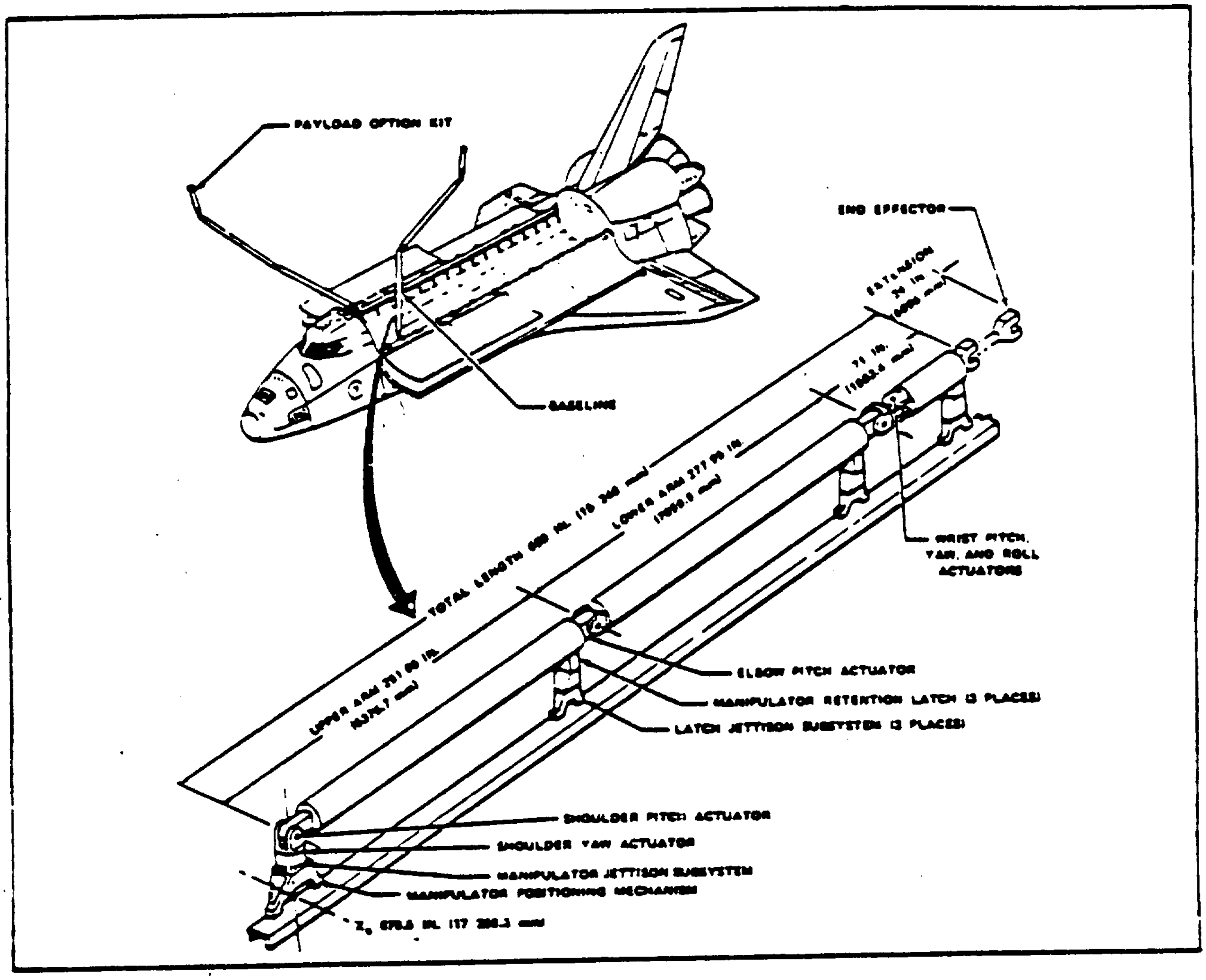


Figure B-9. Manipulator arm assembly location on the Orbiter.

Customer requirements for these additional services are defined on a case-by-case basis and must be negotiated in the PIP. This section describes some of the nonstandard services available. For detailed specifications and interface characteristics, contact the JSC Customer Integration Office.

B.4.1 Auxiliary DC Power

Auxiliary 28 Vdc power can be provided in the payload bay if additional redundancy is required for payload safeing. Power up to 400 watts is available during ascent, on orbit, and entry.

B.4.2 AC Power

Three-phase, 115 Vac electrical power can be provided in the payload bay at the SIP. Power levels of 690 volt-amps during on-orbit and ground operations and 350 volt-amps during descent and post-landing mission phases are available. During ascent TBD volt-amps are available.

B.4.3 Standard Umbilical Retraction and Retention System (SURS)

The SURS is used as the electrical interface between the payload and the right and left standard interface panel (SIP) connectors.

B.5 Induced Environments

Payload environments will vary for specific missions and will also depend on the instrument configuration involved. Therefore, data in this section are general in nature. The figures represent recommended design qualification test levels.

B.5.1 Vibration Caused by Noise

The Orbiter is subjected to random vibration on its exterior surfaces by acoustic noise (generated by the engine exhaust) and by aerodynamic noise (generated by airflow) during powered ascent through the atmosphere. These fluctuating pressure loads are the principal sources of structural vibration. Actual vibration input to payloads will depend on transmission characteristics of cargo bay payload support structure (APAE) and interactions with each payload's weight, stiffness, and center of gravity.

Vibration resulting from acoustic spectra is generated in the cargo bay by the engine exhaust and by aerodynamic noise during atmospheric flight.

B.5.2 Payload Limit Load Factors

Payload structure and substructure must be designed with the appropriate margin of safety to function during all expected loading conditions, both in flight and during ground handling. The limit load factors for deck carrier and MPA mounted payloads are shown in **Figure B-10** The limit load factors are to be applied in the most critical direction only. The recommended margin of safety to apply to these limit load factors is 1.5.

B.5.3 Pressure and Venting

With the vents open, the cargo bay pressure closely follows the flight atmospheric pressures. The payload vent sequencing is as follows: (N.B. During the orbital phase, the cargo bay operates unpressurized.)

Prelaunch	Closed (vent no. 6 in purge position)
Lift-off (T = 0)	Closed
T + 10 seconds	All open
Orbit insertion	All open
On orbit	All open
Pre-entry preparation	All closed
Entry (high heat zone)	All closed
Atmospheric entry to landing	All open
Post-landing purge	Closed (vent no. 6 in purge in position)

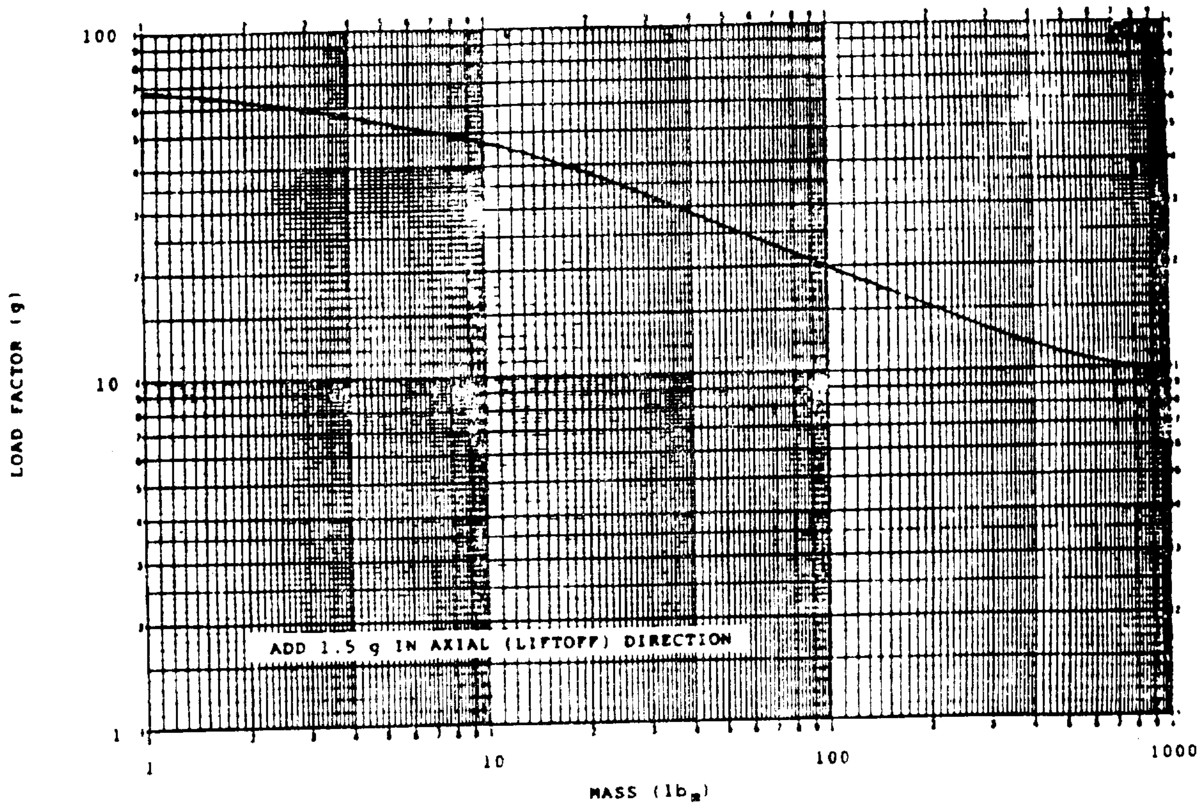


Figure B-10. Load factors for component mountings.

B.5.4 Contamination Control

A contamination control system, including various techniques to eliminate or minimize contamination, is provided by the Orbiter design and standard flight plans. The sensitivity of most payloads to contamination is recognized and each mission can be tailored to meet specific requirements. Before lift-off and after landing, the cargo bay is purged and conditioned as specified in the description of thermal controls. At launch and during early ascent, the cargo bay vents are left closed to prevent exhaust products and debris from entering the bay. During final ascent and through orbit insertion, the cargo bay is depressurized and the payload is generally not subjected to contaminants. On orbit there are three major sources of contamination: reaction control subsystem vernier firings, dumping of potable water, and release of particulates and outgassing.

During deorbit and descent, the cargo bay vents are closed to minimize ingestion of contaminants created by the Orbiter systems. During the final phase of reentry, the vents must be opened to re-pressurize the Orbiter. To help prevent contamination during this phase, the vents are located where the possibility of ingestion is minimal.

Appendix C: Worst Case Payload Environments, all phases (TBR)

Humidity, ground: 8 to 100% RH

Ozone, surface: max 3 to 6 phm (parts per hundred million)

Shock: 20g terminal sawtooth shock pulse with 11 msec duration

Acceleration, ground: 2g vertical ± 20° cone angle

Acceleration, mission: ±5g in each major direction

Temperature: -65°F to +150°F for 6 hours, max =190°F for 1 hour.

Appendix D: Definitions

Attached Payload Accommodation Equipment (APAE). Space Station Freedom Program User support hardware designed to secure attached payloads to the Space Station Freedom Manned Base structure, as well as to provide utilities, command and control, and cooling to the attached payloads.

Design Reference Mission. A Design Reference Mission is an integrated model of SSFMB operations, including SSFMB and User operations, User payload operations and external element interfaces. DRMs will be used to assess the adequacy of Space Station Freedom systems, configurations and operations design to accommodate selected operations scenarios and User support. Each DRM includes a payload set selected to match the User support emphasis provided by the DRM.

Discipline Operations Center. A Discipline Operations Center is a User supplied location providing support to a discipline User group oriented towards a specific area of investigation wherein Users could share technical interests and common overhead costs. A DOC is also a specific type of User operations facility that coordinates operations among local discipline Users, or with other proprietary User operations facilities in the same discipline, during flight preparation and execution. Examples of User group disciplines include; materials sciences, life sciences, astro/solar/planetary physics, commercial production, etc.

Distributed Systems. Systems in which end-to-end performance is located in two or more elements.

Element: A Space Station Freedom element is one of the major components of the system. Elements include the pressurized modules, truss structure, attached payloads accommodations equipment, solar arrays (and associated equipment), platforms, and servicing facilities. Not all of the elements are available at start up of the program. This document focuses on the Space Station Freedom Program Element (SSFPE) called Attached Payloads Accommodations Equipment or APAE.

Engineering Support Center. Engineering support centers shall provide on-call and real-time consultation and sustaining engineering support and the repository for the technical characteristics for the flight and ground systems hardware, during the development phases and operational phases of t

Increment. Increment is the term denoting a mission planning element, comprising all operations during the interval between consecutive NSTS arrivals at the SSFMB, and all prelaunch planning and preparatory activities associated with that increment.

Mission: A mission is the period of time in which a payload (or experiment) is utilized to accomplish objectives.

Payload: A payload consists of hardware and software designed to accomplish a specific scientific, technical or commercial objective (or set of objectives). Some payloads are considered as Facility Class payloads; i.e. the hardware and software is capable of meeting many different types of objectives within a particular discipline. For the purposes of this document an attached payload is a payload that attaches to the SSFMB via the APAE.

Payload Operations Integration Center (POIC). The Payload Operations Integration Center is a Space Station Program supplied facility to integrate User payload operations activities into the Manned Base. The POIC provides the focal activity for the distributed User operations facilities to develop an integrated User operations execution plan on an increment-by-increment basis, and supports the real-time management of in-flight departures from those plans.

Regional Operations Center (ROC). A Regional Operations Center is a User-supplied, geographically focused location providing support to regionally based User groups wherein Users could share technical interests or common overhead costs. A ROC includes facilities that can support User operations integration functions such as coordinating operations among local Users, discipline centered Users, or with other proprietary User operations facilities during flight preparation and execution.

Payload Integration Center (PI Center). A payload integration center for attached payloads and equipment located at NASA GSFC, the WP3 facility, or other site as directed by the GSFC.

Space Station Freedom Control Center (SSFCC). The Space Station Freedom Control Center provides centralized systems management and control for the Manned Base, including the elements provided by the International Partners, and has the safety responsibility for the crew and Manned Base. The SSFCC also provides the integrated plan for User and systems activities based on the criteria for overall systems integrity, crew operations effectiveness, and crew safety. The SSFCC monitors the systems status of the Manned Base, relays commands to support general systems operations and insures that safety requirements are met. Crew training facilities are closely associated with the SSFCC.

System: The Space Station Freedom system consists of all the individual elements of the program taken together as a whole.

Torque Equilibrium Attitude. Torque Equilibrium Attitude is the SSFMB orientation which minimizes momentum requirements on the control system by balancing a disturbance torque, e.g. aerodynamic drag, with another disturbance torque, e.g. gravity gradient. The attitude is described by a set of three angle rotations about the body axes: pitch, yaw and roll sequence.

Trial Payload Manifests . Trial Payload Manifests are the set of payload data used to conduct Space Station Freedom design accommodations studies related to time-phased payload accommodations not covered by Design Reference Missions. TPMs do not represent actual manifesting of payloads or of payload support equipment, consumables, spares, etc.

User: A User is any scientific, technical, or commercial sponsor of a use of a Space Station Freedom Element. A User may be either private or government, domestic or international. A User may be a single individual (Principal Investigator) or a collection of individuals in the case of a Facility class payload.

Appendic E: Acronym List

A/D	Analog to Digital
A&M	Assembly and Maintenance
A&R	Automation and Robotics
a/c	Alternating Current
ACA	Attitude Control Assembly
ACD	Architectural Control Document
ACS	Attitude Control System
ADC	Analogue to Digital Converter
ADP	Automated Data Processing
ADPE	Automatic Data Processing Equipment
ADS	Attitude Determination System
AH	Attitude Hold
a/k/a	also known as
AOC	Accommodation Operating Capability
AME	Antenna Mounted Equipment
AMU	Atomic mass unit
APA	Attached Payload Accommodations
APAE	Attached Payload Accommodation Equipment
APM	Astronaut Positioning Mechanism
APS	Astronaut Positioning System
APT	Automatic Picture Transmission
ASE	Airborne Support Equipment
ATAC	Advanced Technology Advisory Committee
ATCS	Active Thermal Control System
ATS	Assembly Trusses and Structures
BCD	Baseline Configuration Document
BCU	Bus Control Unit
BER	Bit Error Rate
BIA	Bus Interface Adapter
BIT	Built in Test
BITE	Built-In Test Equipment
BOE	Basis of Estimate*
bps	Bits Per Second
BW	Bridge Wire
C	Centigrade
C of F	Construction of Facilities
C&CS	Communication & Control System
C&M	Control and Monitoring
C&T	Communications and Tracking
C&W	Caution and Warning
C/C	Command and Control
CAD	Computer Aided Design/Drafting
CAE	Computer Aided Engineering
CAI	Computer Aided Instruction
CAUSE	Computer Aided User-Oriented Systems Evaluation
CB	Circuit Breakers
CBC	Closed Brayton Cycle
CCB	Configuration Control Board
CCCN	Customer Coordination Center Node
CCTV	Closed Circuit Television

CDD	Connect Disconnect Device
CDR	Critical Design Review
CE&IS	Combined Elements & Integrated Systems
CEI	Contract End Item
CEI	Configuration End Item
CETF	Critical Evaluation Task Force
CFM	Cubic Feet Per Minute
CFRP	Carbon Fiber Reinforced Plastics
CG	Center-of-gravity
CIL	Critical Items List
CIN	Center Information Network
CITE	Cargo Integration Test Equipment
CM	Control Module
CMD	Command
CMDM	Controller Multiplexer/Demultiplexer
CMG	Control Moment Gyro
CMS	Contamination Monitoring System
CMU	Contamination Monitoring Unit
COB	Close of Business
COMS	Communication System
COP	Co-orbiting Platform
COTS	Commercial Off-the-Shelf
COUP	Consolidated Operations and Utilization Plan
CPT	Comprehensive Performance Test
CPU	Central Processing Unit
CR	Change Request
CSCI	Computer Software Configuration Item
CSF	Customer Servicing Facility
CSS	Crew Support Station
CUP	Consolidated Utilization Plans
D/A	Digital to Analogue
DAC	Digital to Analogue Conversion
DBMS	Data Base Management System
DC	Deck Carrier
dc	Direct Current
DDT&E	Design, Development, Test and Evaluation
DES	Data Exchange System
DIAPR	Data Integrity and privacy Requirement
DKC	Design Knowledge Capture
DME	Data Management Equipment
DMPS	Data Management Processing Equipment
DMS	Data Management System
DOC	Discipline Operations Center
DOD	Department of Defense
DOD	Depth of Discharge
DOF	Degree of Freedom
DPD	Data Procurement Document
DR	Data Requirement
DRC	Data Routing Center
DRL	Data Requirement List
DRM	Design Reference Mission
DRS	Data Relay Satellite
DTC	Design to Cost

EAC	Engineering Analysis Capability
ECLS	Environmental Control and Life Support
ECLSS	Environmental Control and Life Support Sys.
EDP	Embedded Data Processor
EEE	Electrical, Electronic and Electromechanical
EEU	Extravehicular Excursion Unit
EF	Exposed Facility
EFRGF	Electrical Flight Removable Grapple Fixture
EGSE	Electrical Ground Support Equipment
EIU	Electrical Interface Unit
ELM	Experiment Logistics Module
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Capability
EMI	Electromagnetic Interference
EMS	Engineering Master Schedule
EMT	Early Man Tended
EMU	Extravehicular Maneuvering Unit
EPS	Electrical Power System
ERS	European Relay Satellite
ES	Equipment Section
ESA	European Space Agency
ESC	Engineering Support Center
ETR	Eastern Test Range
EVA	Extravehicular Activity
EVAS	Extravehicular Activity System
F	Fahrenheit
FAR	Federal Acquisition Regulation
FDIR	Fault Data Identification and Reporting
FDIR	Fault Detection, Isolation and Reconfiguration
FDM	Frequency Data Multiplexer
FEL	First Element Launch
FF	Free Flight
FMEA	Failure Modes and Effects Analysis
FMS	Fluid Management System
FMS	File Management System
FRGF	Flight Removable Grapple Fixture
FSE	Flight Support Equipment
FSM	Fuel Supply Module
FSS	Flight Support Structure
ft	Feet
FTS	Flight Telerobotic Servicer
g	Acceleration of Gravity
GDMS	Ground Data Management System
GFE	Government Furnished Equipment
GFP	Government Furnished Property
GHz	Gigahertz
GMT	Greenwich Mean Time
GN&C	Guidance, Navigation, and Control
GPS	Global Positioning System
GS	Gas Servicer
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center

HAB	Habitation Module
HBC	Hyperbaric Chamber
HGA	High Gain Antenna
HLCM	High Level Control Module
HMF	Health Maintenance Facility
HR	Hour
HRM	High Rate Multiplexer
HRPT	High Resolution Picture Transmission
HSO	Habitation/Station Operations
HST	Hubble Space Telescope
HSTF	High Speed Telemetry Formatter
H/W	Hardware
HX	Heat Exchanger
IACO	Integration Assembly & Checkout
ICD	Interface Control Document
ICM	Increment Change Manager
I/O	Input/Output
IEP	Integrated Execution Plan
IF	Intermediate Frequency
ILSS	Integrated Logistic Support System
IMC	Intermodule Connector
IMC	Image Motion Compensation
IMS	Inventory Management System
in	inch
IOC	Integrated Operations Configuration
IPV	Individual Pressure Vessel
IRU	Inertial Reference Unit
ISA	Inertial Sensor Assembly
ISO	International Standards Organization
IT&V	Integration Test and Verification
ITVF	Integrated Test and Verification Facility
IV&V	Independent Verification and Validation
IVA	Intravehicular Activity
IWG	Investigator Working Group
JSC	Johnson Space Center
JEM	Japanese Experiment Model
kg	Kilogram
kHz	Kilohertz
km	Kilometer
KSA	Ku-Band Single Access
KSC	Kennedy Space Center
kW	Kilowatt
LAN	Local Area Network
LCD	Left Circular Polarized
LeRC	Lewis Research Center
LGA	Low Gain Antenna
LIS	Logistics Information System
LNA	Low Noise Amplifier
LO	Local Oscillator
LOE	Level of Effort
LOS	Line of Sight
LPC	Load Power Conditioner
LSE	Launch Site Equipment

LSSM	Launch Site Support Manager
LVDT	Linear Variable Differential Transducer
LVLH	Local Vertical-Local Horizontal
m	Meter
M&SS	Mission and Simulation Software
MA	Multiple Access
MBA	Multiple Berthing Adapter
Mbps	Megabits per second
MBSA	Main Bus Switching Assembly
MBSU	Main Bus Switching Unit
MCC	Mission Control Center
MDM	Multiplexer Demultiplexer
MFR	Mobile Foot Restraint
MGSE	Mechanical Ground Support Equipment
MIDK	Machine Intelligible Design Knowledge
MIPS	Million Instructions per Second
MLI	Multilayer Insulation
MMA	Moving Mechanical Assembly
MMD	MSC Maintenance Depot
MMH	Monomethyl Hydrazine
MMU	Mass Memory Unit
MOU	Memorandum of Understanding
MPA	Multiple Payload Adapter
MPAC	Multipurpose Application Console
MRDB	Mission Requirements Data Base
MRS	Mobile Remote Servicer
MSC	Mobile Servicing Centre
MSFC	Marshall Space Flight Center
MSU	Mass Storage Unit
MT	Mobile Transporter
MTC	Man-Tended Configuration
MTU	Master Timing Unit
MTTC	Min. Telemetry & Telecommand Controller
M W	Mobile Workstation
N	Newton
N/A	Not Applicable
NASA	National Aeronautics & Space Administration
NASCOM	
NBSA	Node Bus Switching Assembly
NIU	Network Interface Unit
nmi	Nautical Mile
Nms	Newton Meter Seconds
NOS	Network Operating System
NSI	NASA Standard Initiator
NSTS	National Space Transportation System
NTO	Nitrogen Tetroxide
O&C	Operations & Checkout
O&M	Operations and Maintenance
OD	Outside Diameter
OFS	Orbiter Functional Simulator
OMA	Operations Management Application
OMS	Operational Management System

OMV	Orbital Maneuvering Vehicle
ORR	Operations Readiness Review
ORS	Orbital Refueling System
ORU	Orbit Replacement Unit
OS	Operating System
OSCRS	Orbital S.C. Consumables Resupply Sys.
OSE	Orbital Support Equipment
OSI	Open Systems Interconnect
OTV	Orbital Transfer Vehicle
P/O A	Payload/ORU Accommodations
PA	Power Amplifier
PAE	Payload Accommodations Equipment
PAM	Payload Accommodations Manager
PAS	Payload Attachment System
PCR	Payload Checkout Room
PCS	Payload Checkout Station
PCU	Power Conditioning Unit
PCU	Power Conversion Unit
PDCA	Power Distribution and Control Assembly
PDCU	Power Distribution & Control Unit
PDR	Preliminary Design Review
PDRP	Program Definition and Requirements Document
PEP	Portable Emergency Provision
PGS	Power Generating System
PI	Payload Integration
PIA	Payload Interface Adapter
PIMS	Plasma Interactions Monitoring System
PIU	Power Interface Unit
P/L	Payload
PLC	Pressurized Logistics Carrier
PLCS	Pressurized Logistics Carrier Structure
PLM	Pressurized Logistics Module
PLM	Pressurized Laboratory Module
PM	Pressurized Module
PMAD	Power Management and Distribution
PMC	Permanently Manned Capability
PMS	Performance Measurement System
PMS	Platform Management System
PMMS	Process Materials Management Subsystem
PNIU	Partial Network Interface Unit
POCC	Payload Operations Control Center
POIC	Payload Operations Integration Center
POP	Polar Orbiting Platform
PPS	Payload Pointing System
PRR	Preliminary Requirements Review
PS	Power Supply
PSCN	Program Support Communications Network
PSF	Payload Servicing Facility
PTC	Payload Training Centert
PTCS	Passive Thermal Control System
PTU	Pan Tilt Unit
PV	Photovoltaic
R&I	Receiving and Inspection

RBI	Remote Bus Isolator
RCB	Reaction Control Board
RCP	Right Circular Polarized
RCS	Reaction Control System
RF	Radio Frequency
RFI	Radio Frequency Interference
RFP	Request for Proposal
RMS	Remote Manipulator System
ROC	Regional Operations Center
RNIU	Remote Network Interface Unit
RPC	Remote Power Controller
S&T	Science and Technology
S/C	Subcontract
S/S	Subsystem
S/W	Software
SAAR	Small and Rapid Response Payloads
SC	Supervisor Call
SDM	Structural Development Model
SDP	Standard Data Processor
SIA	(Space) Station (Freedom) Interface Adapter
SPDM	Special Purpose Dextrous Manipulator
SPM	Solar Power Module
SS(F)	Space Station (Freedom)
SSCB	Space Station (Freedom) Control Board
SSCC	Space Station (Freedom) Control Center
SSCBD	Space Station (Freedom) Control Board Directive
SSIS	Space Station (Freedom) Information System
SSM	Systems Support Module
SSFMB	Space Station Freedom Manned Base
SSFP	Space Station Freedom Program
SSME	Subsystem Support Module - Electrical
SSMT	Subsystem Support Module - Thermal
SSPE	Space Station (Freedom) Program Element
SSTF	Space Station (Freedom)Training Facility
SSPF	Space Station (Freedom) Processing Facility
STA	Service Track Assembly
STA	Shuttle Training Aircraft
STD	Standard
STDN	Space Tracking and Data Network
STP	Short Term Plan
STS	Space Transportation System
SYS	System
Tb	Terabyte
TBD	To Be Determined
TBR	To be Resolved
TBS	To Be Supplied
TCS	Thermal Control System
TCU	Telecommand Control Unit
TDRS	Tracking & Data Relay Satellite
TDRSS	Tracking & Data Relay Satellite System
TDU	Time Distribution Unit
TGS	Time Generation Subsystem

TMIS	Technical and Management Information System
TMM	Thermal Math Module
TOP	Tactical Operations Plan
TRR	Thermal Radiator Rotation
TSS	Telerobotic Safing System
TT&C	Telementry, Tracking and Control
TTG	Transfer Time Generator
TV	Television
TWTA	Traveling Wave Tube Assembly
U/D	Update
UCDD	Utilities Connect Disconnect Device
UHF	Ultrahigh Frequency
UIA	User Interface Adapter
UIL	User Interface Language
ULC	Unpressurized Logistics Carrier
UOF	Users Operations Facility
U.S.	United States
USL	United States Laboratory
UST	Universal Servicing Tool
UTC	Universal Time Coordinated
VBIU	Video Bus Interface Adapter
VME	Versa Module Europe
W	Watt
WAN	Wide Area Network
WFMS	Waste Fluid Management System
WP	Work Package
WTR	Western Test Range
XFG	Transfer Frame Generator
XMTR	Transmitter
ZOE	Zone of Exclusion